Flora W. Patterson

EXPERIMENT STATION.

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KANSAS STATE

AGRICULTURAL COLLEGE.

Bulletin No. 62—December, 1896.

BOTANICAL DEPARTMENT.

CORN SMUT.

A. S. Hitchcock.
J. B. S. Norton.

MANHATTAN, KAS.
1896.

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EXPERIMENT STATION

OF THE

KANSAS STATE AGRICULTURAL COLLEGE,

MANHATTAN.

BULLETIN No. 62—DECEMBER, 1896.

BOTANICAL DEPARTMENT.

A. S. HITCHCOCK, M. S., Professor of Botany.
J. B. S. NORTON, B. S., Assistant in Botany.*

CORN SMUT.

The smut of corn is caused by a lowly-organized plant which lives as a parasite upon the corn plant. It is similar in some respects to the rust of wheat, the mildew of the grape, and the scab of the apple. The smut plant consists of numerous minute threads which penetrate the substance of the corn plant. These threads are so fine that they can be seen only with a microscope. The threads absorb the juice of the corn, and thus rob the latter of the nourishment which should go to form seed. After a time the smut plant produces spores. These spores are very small, but are aggregated into masses containing countless numbers of the spores. These masses form the unsightly smut boils which are familiar to all. The spores of the smut serve the same purpose as the seeds of larger plants—that is, they propagate the smut. They are so small and light that they are easily blown about by the wind, thus scattering the disease far and wide.

It is the purpose of this bulletin to record observations and experiments made during the past three years upon the life-history of the smut, and upon the conditions favoring the spread of the disease.

*Although Mr. Norton resigned his position in September, his name is retained in this bulletin because of his responsibility for a large part of the work reported. His successor, Mr. G. L. Clothier, also rendered much assistance.

AMOUNT OF DAMAGE CAUSED BY SMUT.

It is difficult to estimate the amount of damage caused by smut because the plants may be injured in such different degrees. Table I gives the results obtained on a field used for the purpose of estimating the damage. This field was about a quarter of an acre of good ground; was well cultivated, and yielded well. The smutted stalks were marked during the summer and fall, and in October the ears from each row were weighed, those from smutted stalks and clean stalks being kept separate. Among the smutted stalks are included all on which a trace of smut could be found on stalk, ears, leaves, or any other part.

Table I.

Row No. (in Plat.)	Clean.			Smutted.		
	Number of stalks.	Total weight of grain.	Average weight per stalk.	Number of stalks.	Total weight of grain.	Average weight per stalk.
33	35	7,635	218	22	2,200	100
34	36	4,205	117	22	1,091	49
35	30	4,400	146	15	1,862	124
36	30	2,155	71	17	1,950	114
37	31	4,350	140	14	1,220	87
38	41	4,220	103	15	1,990	132
39	39	5,655	145	15	1,990	132
40	37	7,430	201	9	1,475	164
41	45	9,105	202	13	1,205	92
42	46	8,035	174	18	1,765	98
43	35	3,540	101	25	3,215	128
44	60	10,285	171	17	2,865	168
45	63	8,795	139	15	2,060	137
46	67	11,055	165	14	1,040	74
47	58	11,725	202	12	1,075	89
48	60	12,700	110	15	2,220	148
49	44	9,335	212	17	2,740	161
50	54	12,075	223	9	1,545	171
51	.....	1,445	.....	10	955	95
52	93	17,520	278	5	865	173
53	.....	2,935	.....	3	530	176
54	91	12,055	197	21	4,295	204
55	.....	375	.....	5	490	98
56	48	11,765	245	13	2,750	211
57	55	12,345	224	16	1,325	82
58	41	6,985	170	12	1,745	145
59	64	12,925	202	16	1,590	99
60	53	11,075	209	27	3,205	118
61	57	10,775	189	15	1,235	82
62	55	11,170	203	18	2,680	149
63	62	12,875	207	12	1,655	138
64	46	9,655	209	23	2,575	112
65	55	12,585	228	14	1,525	109
66	55	11,405	207	17	2,535	148
67	42	11,255	268	19	2,250	118
68	51	10,070	199	10	1,945	194
69	43	9,999	233	19	2,781	146
70	53	11,183	211	12	2,268	186
71	32	4,494	140	20	2,309	115
72	51	11,995	235	12	1,985	165
74	42	8,670	206	15	2,280	150
75	42	11,125	265	20	2,640	132
76	33	9,100	270	12	1,290	107
77	38	6,195	163	16	1,920	120
78	28	5,320	190	12	1,055	88
79	22	4,385	199	11	815	74
80	43	8,215	191	9	1,105	122
81	28	6,115	218	13	1,955	150
82	36	6,585	183	14	1,555	111
83	27	6,505	270	11	1,190	108
84	31	5,455	176	6	820	136

The figures show that the average weight of corn on the clean stalks was 193 grams, or about six ounces, and that the average weight on the smutted stalks was 126 grams, or about four ounces; that is, the smutted stalks bore one-third less corn than the clean stalks. It must be remembered that many of the stalks included in calculating the average of the smutted stalks were only slightly injured, while on the other hand some stalks were so badly smutted that they bore no corn at all.

It is possible that these stalks were inherently weaker, and hence were more subject to the attack of the smut, and that they would not have borne as much corn even if unsmutted. But field observations indicate that the weak stalks are less likely to be smutted.

The loss in the smutted corn is chiefly in the grain. The stalks are nearly or quite as heavy in the smutted as in the sound corn. Table II gives a record upon this point.

It will be seen from this table that the average weight per stalk of the smutted corn is 225 grams, or seven ounces, while the average weight of the stalk of clean corn in the same two rows is 229 grams —practically the same. On the other hand, the ears on the smutted corn averaged 162.8 grams, or about five ounces per stalk, while the ears on the clean corn averaged 213.3 grams per stalk. This represents a loss of 23.6 per cent. in weight of ears for the smutted corn.

Table II.—Weight of Stalks and Ears of Smutted and Clean Corn.

Row No.	Smutted.					Clean.				
	Number of stalks.	Weight of stalks.		Weight of ears.		Number of stalks.	Weight of stalks.		Weight of ears.	
		Total.	Average.	Total.	Average.		Total.	Average.	Total.	Average.
69.....	19	4,421	233	2,781	146	43	11,540	268	9,999	233
70.....	12	2,578	215	2,268	186	53	10,648	201	11,183	211

The total damage in a field of corn depends upon the proportion of smutted stalks. This is a very variable quantity. Table I shows that, out of a total of 2,984 stalks, 724 were more or less affected by smut. Table III gives detailed observations on a number of fields. The percentage is seen here to rise as high as 26 per cent. This is, however, unusual; 6 per cent. will probably represent the average.

During the summers of 1894, 1895, and 1896, extensive notes have been made upon a large number of corn-fields, mostly in the vicinity of Manhattan. It was intended to take note of all conditions that might possibly affect the production of smut on the corn. In most cases there were noted the variety of corn, location of field, kind of

soil, date and method of planting, state of cultivation, previous crop, stage of development, date of taking the notes, number of stalks counted, and number of these that were smutted. Note was also made of the part of the plants smutted in each case.

During the three years, over 200,000 corn plants have been examined, in about 500 fields, which varied as much as possible in all the conditions included in the notes. The following is a tabulation of a few of the most characteristic fields examined, and includes as well all those in which any particulars worthy of note were observed. The different counts are arranged according to the stage of advancement, commencing with the youngest. This table shows chiefly the parts of the corn plant affected by the smut. It will be seen that in June and July the leaves are the parts most frequently attacked. Later on other parts, especially the nodes, are frequently attacked. The ears are less frequently affected, but of course most of the damage is caused by the occurrence of the smut in this part.

Table III.

SMUT PERCENTAGE, AND OTHER NOTES.

Date.	Variety.	Total stalks.	Smutted stalks.	Per cent. smutted.	Part of plant infected.								Stage of development.	Soil.	Cultivation.	Time of planting.	Previous crop.	Remarks.
					Leaves.	Node.	Internode.	Brace roots.	Suckers.	Rudimentary ears.	Ears.	Tassel.						
8-16-'95	Field	300											1-2 feet high	Sandy loam	Clean	July	Small grain this year	
6-22-'95	Mosby's Prolific	385	12	3.1	12								4 feet high	Upl'd, clayey,	"	Apr. 27	Wheat	Listed.
6-29-'95	Field	573	4	0.7	4								1-3 feet high				Not corn.	
7- 8-'95	Mosby's Prolific	600											4-5 "	Upland, good,			Wheat	Drilled; ensilage corn.
7- 1-'95	Field	600	29	4.8	29								2-5 "	Rich upland				Drilled; most of the smut in a ravine.
7- 1-'95	"	1,000	9	0.9	9								5 feet high	Rich loam	Clean			Too thick and slender; smut on better stalks.
7- 1-'95	"	600	27	4.5	27								5 "	"	"			Thick, but much smut on 7th and 8th leaves.
6-27-'95	"	200	32	16.0	32								3-5 feet high	Rich bottom				Listed; on 6th to 9th leaves.
6-29-'95		700	15	2.1	15								4 feet high	Rich loam				Tall; ensilage corn.
6-29-'95	Field	600	46	7.7	45							1	Tasseling	Good upland	Fair		Corn	Listed.
6-26-'95	"	500	39	7.8	35	1						3	"	Upland	Clean	Apr. 22	Wheat	Surface drilled.
7-11-'95	"	500	2	0.4	2								"	Sandy loam	"		Not corn	Drilled.
7-18-'95	"	300	18	6.0	15	1	2		2	3			"	Rich bottom	"			
7-22-'95	Leaming	500	33	6.6	32	2	2		5	2			"	Clayey bot'm,				Listed.
6-29-'95	"	663	5	0.8	5								Few tassels	Light upland,	Clean	Apr. 24	Sorghum	Surface planted.
7-18-'95		396	4	1.0	3	1							Tass'g & silk'g			Apr. 18	Beans	
9-19-'94	Early field	2,800	14	0.5	14								Tasseled	Sandy loam		June 20	Wheat	
7-27-'94	Peach Blossom Mam.	300	26	8.8	17	7		1			3		"	Heavy, manured	Good		Corn	
7-28-'94	Field	500	26	5.2	25	1			1		1		"					Listed.
7-28-'94	"	600	20	3.3	16	7						2	"	Rich, s'dy l'm,	Clean			Listed; better corn had more smut.
7-30-'94	"	400	13	3.3	11		2				1	2	Silked	Sandy loam	Good	May 10	Corn	Listed.
8- 1-'94	"	500	30	6.0	18	5	5					1	Well tasseled,	Rich loam	Clean	May 20	"	Planted.
8-10-'94	Mam. White Surprise	450	15	3.3	10	6						1	Just in tassel,	Good upland	"		Wheat	Late variety.
7- 1-'95	Field	400	25	6.3	21						1	4	Tasseling	Light upland,	G'd surface,		Wheat and late corn	Listed.

Table III — *Concluded.*

Date.	Variety.	Total stalks.	Smutted stalks.	Per cent. smutted.	Part of plant infected.								Stage of development.	Soil.	Cultivation.	Time of planting.	Previous crop.	Remarks.
					Leaves.	Node.	Internode.	Brace roots.	Suckers.	Rudimentary ears.	Ears.	Tassel.						
7- 1-'95	Field	800	119	14.9	98	1	...	10	3	1	...	9	Tasseling	Light upland,	G'd surface,	...	Wheat	Poorer corn had less smut; near horse stable.
7-10-'95	"	400	26	6.5	24	4	5	...	...	5	...	1	Tass'g & silk'g	Rich s'dy l'm,	Clean	...	Corn	Drilled.
7-12-'95	"	460	...	...	...	...	...	...	...	...	...	...	Tasseling	Rich bottom..	"	...	New ground	Very excellent corn.
7-12-'95	"	500	2	0.4	1	...	...	...	...	...	...	1	Silking	Clayey upl'd..	...	...	...	Drilled.
7-20-'95	"	200	40	20.0	31	15	13	...	...	11	2	1	"	Upland	...	...	...	Dril'd; badly smutted.
7-22-'95	"	300	41	13.7	39	1	1	...	2	...	...	1	Tasseling	Rich bl'k l'm,	Poor	...	Corn	Stalks slender, thick in hills.
8-13-'95	"	200	2	1.0	1	...	...	...	...	...	1	...	"	Bottom land..	Clean	Late	New ground	Rank growing.
8-16-'95	"	150	1	0.7	...	...	...	...	...	...	1	...	"	Sandy bott'm,	"	"	Oats this year	Listed in oats.
7-10-'95	"	200	20	10.0	18	...	1	...	...	...	...	2	Tass'g & silk'g	...	...	...	...	...
7- 9-'95	Fisk	400	14	3.5	8	5	5	...	2	...	...	2	Ears half gr'n	Rich upland..	Fair	April 10.	Corn	Very rank growth.
7- 8-'95	Field	800	16	2.0	10	2	2	...	...	...	...	2	Tass'd & silk'd	Very rich bot.	...	...	...	Drilled.
8- 6-'94	Sweet	500	4	0.8	3	...	...	...	1	...	1	3	Tasseled	Sandy	Fair	...	...	"
8- 3-'94	Field	700	47	6.7	10	21	1	...	3	...	6	4	In tassel	Sandy loam..	Ridged	May 15..	Potatoes	In hills.
8- 2-'94	"	1,000	25	2.5	13	8	1	...	...	...	...	1	Tasseled	Rich s'dy l'm,	"	May 10..	Corn	Drilled.
7-30-'94	"	500	47	9.4	46	1	7	...	...	...	4	1	Silks dying	Light sandy..	"	May 15..	Corn & wheat	...
7- 1-'95	"	300	32	10.7	23	3	...	...	...	1	1	2	Silking	Yellow clay ..	Fair	May 10..	...	Listed.
6-29-'95	Sweet	400	23	5.8	3	4	2	...	6	...	3	9	Silks dying	Rich bottom..	Good	...	Wheat	...
7-20-'95	Field	400	35	8.8	28	4	4	...	...	2	3	3	Earing	Very sandy	Clean	...	Corn	Drilled.
7-20-'95	Sweet	300	1	0.3	1	...	...	...	...	...	...	...	Silks dying	Upland	Fair	...	...	In hills.
7-22-'95	Field	400	33	8.3	27	2	2	...	2	4	2	1	"	Rich bottom..	Clean	...	Corn	Smut in patches in the field; drilled.
8- 1-'95	"	566	9	1.8	3	1	1	...	...	1	...	...	"	2d bottom	"	...	"	Drilled.
8-12-'95	"	200	29	14.5	...	1	1	...	11	18	1	...	"	Upland	"	...	...	Drilled thick.
7-16-'95	"	400	20	5.0	7	7	7	...	...	5	4	4	"	"	"	May 16.	...	Drilled; many stalks entirely destroyed.
7-27-'94	E'y yel'w f'd	600	35	5.8	9	20	...	...	2	...	2	6	Y'g r'st'g ears	Sandy loam..	"	May 1...	Corn	Listed; only few bottom leaves dead.
7-30-'94	Com'n field,	800	16	2.0	8	4	...	...	...	...	...	2	"	"	"	...	"	Drilled; 40 per cent. dry.
8- 1-'94	Field	500	80	16.0	48	21	8	...	2	...	5	5	...	...	...	...	...	Listed.
8- 3-'94	"	1,100	42	3.8	20	18	2	...	1	...	4	3	...	"	"	May 10..	...	Fifty per ct. dried up.
7- 1-'95	Small sweet	300	51	17.0	...	7	...	...	11	3	28	...	Roasting ears	Black loam ..	Weedy	...	...	In hills; nearly every hill had a smutted stalk.

7-10-'95	Sweet	300	1	0.3	....	....	....	....	1	....	....	....	Ro'sting ears,	Sandy loam	Good	.....	.....	Hills; this one plant is believed to have sorghum smut.
7-22-'95	Field	300	1	0.3	....	....	....	....	....	....	....	1	"	Upland loam,	Not clean	.....	Corn	Drilled.
7-22-'95	"	400	21	5.2	4	4	2	....	8	....	4	....	"	Heavy loam	Fair	.....	.....	"
8- 7-'95	"	800	13	1.6	6	2	3	....	....	7	2	....	"	Light upland,	Good	.....	Corn	Smut in patches in the field; drilled.
8-17-'95	"	600	34	5.7	....	1	1	....	....	29	4	....	"	Thin	Clean	.....	"	Drilled; half of this is injured by chinch bugs.
9-30-'95	"	1,400	3	0.2	....	3	....	....	....	....	....	....	.....	Black loam	Fair	July 12	Oats this year	Listed; smut was all found in thinnest corn.
8-12-'96	.....	300	33	11.0	1	2	1	....	6	24	1	1	In dough	Upland loam,	Clean	May 9	.....	Drilled; smut running out in later corn.
8- 7-'94	Yell'w field,	300	79	26.3	23	22	....	....	5	....	1	33	In "dough"	Sandy	Good	.....	Corn	Drilled.
8- 7-'94	Field	300	55	18.3	15	20	3	....	2	....	5	26	Soft ears	"	Not clean	May 5	.....	Listed.
8- 6-'94	"	500	53	10.6	9	....	....	....	1	5	....	2	"	Sandy bott'm,	Level	May 1	.....	"
8- 1-'94	"	1,000	42	4.2	28	9	1	....	....	....	2	3	Ro'sting ears,	Sandy loam	"	May 15	Wheat	"
8- 1-'94	White field,	600	56	9.3	15	15	2	....	....	....	4	2	"	Rich loam	Weedy	May 10	Corn	"
7-31-'94	Field	500	38	7.6	18	10	6	....	....	....	5	1	"	Rich, s'dy l'm,	.....	May 5	"	
8- 8-'94	"	300	50	16.6	10	37	....	....	1	1	....	3	Soft ears	Sandy loam	Level	May 1	"	"
8- 8-'94	"	500	27	5.4	1	23	....	....	....	....	2	1	"	"	"	"	Prairie grass,	"
8- 8-'94	"	500	27	5.4	1	16	....	....	1	7	....	5	"	"	"	"	"	Drilled.
8- 8-'94	"	500	59	11.8	26	24	2	....	2	....	3	10	"	"	"	"	Corn	"
8- 8-'94	"	800	39	4.9	14	13	....	....	....	....	6	7	H'd r'st'g ears,	Sandy	"	Ap.20,'94	"	Hills.
8- 2-'94	White field,	600	58	9.6	32	18	....	....	....	....	3	5	Soft ears	Sandy loam	Ridged	My10,'94	"	Listed.
8- 1-'94	"	600	47	7.8	17	19	1	....	3	....	1	1	S'ft r'st'g ears,	Rich, s'dy l'm,	Clean level,	May 15	Small grain	Checked in hills.
8-27-'95	Blount's Prolific	300	33	11.0	....	1	1	1	12	17	4	1	Fairly rip'n'd,	Upland loam,	Clean	.....	.....	Drilled.
8-28-'95	Mosby's Prolific	100	26	26.0	....	....	....	....	1	24	1	....	"	Thin, upl. l'm,	"	.....	.....	"
8-21-'95	Field	300	25	8.3	2	3	3	....	10	10	4	....	Hardened	Rich, s'dy l'm,	Good	.....	Corn	"
8- 9-'95	"	200	30	15.0	7	7	5	....	2	16	1	2	Ripening	Rich, bl'k l'm,	Fair.			
8- 5-'95	"	300	28	9.3	12	3	4	1	2	10	....	....	.....	Clay upland.	Weedy	.....	.....	"
7-27-'95	White Rice pop-corn	200	32	16.0	....	3	1	....	8	11	10	2	In "dough"	Loam	Fair	.....	.....	"
7-10-'95	Crosby's Early	300	3	1.0	....	....	....	....	2	....	....	....	Nearly ripe	Sandy	Clean	.....	.....	Hills.
8-27-'95	Leaming	300	16	5.3	1	....	....	....	2	10	2	....	Ripe	Upland loam,	"	.....	.....	Drilled.
8-27-'95	Big B'ckeye,	200	35	17.5	....	....	....	7	....	27	....	2	"	"	"	.....	.....	"
8-28-'95	Peach Blossom Mam.	200	50	25.0	3	....	....	2	4	39	3	....	"	"	"	.....	.....	"

In order to determine their relative susceptibility, observations were made upon a number of varieties cultivated in plats by the farm department. The results are given in Table IV. Although there is considerable difference in the percentage, no variety was found to be smut proof. The percentages run unusually high. The differences are likely to be the result of accident rather than the resistance of particular varieties.

Table IV.

AMOUNT OF SMUT ON DIFFERENT VARIETIES.

Variety.	1895.				August 27, 1895.			August 10, 1894.		
	Date of observation.	Stalks counted.	Stalks smutted.	Per cent. smutted.	Stalks counted.	Stalks smutted.	Per cent. smutted.	Stalks counted.	Stalks smutted.	Per cent. smutted.
Leaming	June 29	663	5	0.76	300	34	11.3			
Gold Mine	July 15	400	14	3.5						
Nebraska Ironclad	"	400	31	7.8	200	29	14.5			
Peach Blossom Mammoth	"	400	20	5.0	200	50	25.0	450	11	2.4
Leaming	"	300	16	5.3	300	34	11.3			
Sterling	"	400	6	1.5	200	30	15.0			
Reardon's Cross	"	400	26	6.5	200	49	24.5			
Golden Beauty	July 16	300	4	1.3	300	28	9.3			
White Cap Yellow Dent	"	400	9	2.2						
Fisk	"	400	8	2.0						
Peach Blossom Mammoth	"	300	5	1.7	200	32	16.0			
Early Mastodon	"	300	12	4.0	200	24	12.0	450	7	1.6
Reardon's Cross	"	300	14	4.7	200	32	16.0			
Early Butler	"	400	20	5.0						
Leaming	"	300	15	5.0	200	20	10.0			
Blount's Prolific	July 9	300	4	1.3	300	33	11.0			
Early Butler	"	300	4	1.3						
Champion White Pearl	"	300	3	1.0	300	36	12.0			
Hickory King	"	300	8	2.7	300	31	10.3			
Champion Yellow Dent	"	300	9	3.0	300	25	8.3			
Mammoth White Surprise	"	300	3	1.0	200	30	15.0			
Leaming	"	300	6	2.0	300	16	5.3			
Mosby's Prolific	"	300	0	0.0	300	29	9.7	450	9	2.0
Big Buckeye	"	400	8	2.0	200	35	17.5			
New England Flint	"	400	4	1.0						
St. Charles	"	300	4	1.3	200	31	15.5			
Fisk	"	400	14	3.5						
Golden Beauty	"	300	8	2.7	300	24	8.0			
Extra Early Huron Dent	"	400	4	1.0						
Early Yellow Rose	"	400	28	6.5	300	36	12.0			

Hickory King	July 8	300	9	3.0		35	17.5					
Mammoth White Surprise	"					29	14.0			15		3.3
Mosby's Prolific	"	300	0	0.0		26	8.7	450				
Deland's Improved	"	300	4	1.3		39	13.0					
Nebraska White	"	300	3	1.0		30	10.0					
Champion White Pearl	"	300	3	1.0		33	11.0					
New England Flint	"	400	2	0.5				450		6		1.3
Blount's Prolific	"	300	1	0.3	200	32	16.0					
St. Charles	July 9	300	0	0.0	300	34	11.3	450		4		0.9
Leaming	"	300	2	0.7	400	39	9.8					
Stooling Flour Corn	"	400	5	1.2	200	37	18.5	450		13		2.9
Chester Mammoth	"	300	6	2.0	300	29	9.7	450		9		2.0
Large Golden Dent												
Pride of Kansas								450		3		.7
Naylor's Improved								450		10		2.2
Hartman's Early White								450		17		3.8
Seek-no-further								450		20		4.4
								450		13		2.9

Table V gives the results of counts made to determine the relation between the amount of smut and the age of the corn. The smut does not usually appear on the plants till they are one to two months old, but counts made late in the season show all about equally smutted regardless of age. The observations were made upon plats of the farm department.

Table V.

RELATION BETWEEN AMOUNT OF SMUT AND AGE OF CORN.

Stalks counted.	Date of planting.	Age in days.	Date of notes.	Stalks smutted.	Per ct. smutted.	Remarks.
1,800	May 31, '94	37	July 7, '94	4	0.2	On leaves.
450	May 17, '94	40	June 26, '94	1	0.2	"
1,800	May 24, '94	44	July 7, '94	8	0.4	"
900	May 10, '94	47	June 26, '94	1	0.1	"
1,800	May 17, '94	51	July 7, '94	23	1.3	"
1,350	May 3, '94	54	June 26, '94	29	2.1	"
1,800	May 10, '94	58	July 7, '94	43	2.4	"
1,350	Apr. 26, '94	61	June 26, '94	27	2.0	"
1,800	May 3, '94	65	July 7, '94	172	9.5	On leaves and nodes.
1,350	Apr. 19, '94	68	June 26, '94	22	1.6	On leaves.
1,800	Apr. 26, '94	72	July 7, '94	97	5.4	On leaves, nodes, and brace roots.
1,800	Apr. 19, '94	79	July 7, '94	107	5.9	" "
200	May 30, '95	73	Aug. 12, '95	36	18.0	Mostly on shoots, and some ears.
200	May 23, '95	80	"	18	9.0	" "
200	May 16, '95	87	"	29	14.5	" "
200	May 9, '95	94	"	27	13.5	" "
200	May 2, '95	103	"	35	17.5	" "
200	Apr. 25, '95	110	"	30	15.0	
200	Apr. 18, '95	117	"	30	15.0	
400	May 29, '96	35	July 3, '96	0	0.0	
400	May 22, '96	42	"	0	0.0	
400	May 15, '96	49	"	0	0.0	
400	May 8, '96	56	"	0	0.0	
400	May 1, '96	63	"	2	0.5	On leaves.
300	May 29, '96	68	Aug. 5, '96	0	0.0	
600	Apr. 24, '96	70	July 3, '96	3	0.5	"
400	Apr. 20, '96	74	"	0	0.0	
300	May 22, '96	75	Aug. 5, '96	8	2.6	On shoots, ears, and suckers.
300	May 15, '96	82	"	6	2.0	" "
300	May 8, '96	89	"	9	3.0	" "
300	May 1, '96	96	"	13	4.3	" "
300	Apr. 24, '96	103	"	28	9.3	" "
300	Apr. 20, '96	107	"	21	7.0	" "

Table VI is a summary of the counts made during the years 1894-1896 to determine the percentage of smut. During the three years, 206,826 stalks were counted, of which 9,716 stalks were smutted. This gives an average percentage of 4.7. The average percentage for all counts made in August is, however, 6.2, which will represent the nearest approach to the true average.

Table VI.

SUMMARY, BY WEEKS, OF THREE YEARS' OBSERVATIONS.

Date by weeks.	Year.	Fields observed.	Stalks counted.	Stalks smutted.	Per cent. smutted.
June, 2d week	1896	11	4,538	28	0.6
June, 3d week	1896	15	5,015	40	0.8
June, 4th week (9 days)	1894	12	5,400	80	1.5
June, 4th week (9 days)	1895	14	6,021	270	4.5
June, 4th week (9 days)	1896	2	800	17	2.1
July, 1st week	1894	31	15,400	664	4.3
July, 1st week	1895	8	4,400	299	6.8
July, 1st week	1896	23	8,000	109	1.7
July, 2d week	1895	21	7,485	160	2.1
July, 2d week	1896	12	5,000	102	2.0
July, 3d week	1895	22	7,896	292	3.7
July, 3d week	1896	5	2,950	5	0.2
July, 4th week (10 days)	1894	28	15,800	623	3.9
July, 4th week (10 days)	1895	14	5,500	250	4.5
July, 4th week (10 days)	1896	7	3,700	30	0.8
August, 1st week	1894	57	32,800	2,021	6.2
August, 1st week	1895	9	3,600	125	3.5
August, 1st week	1896	14	4,600	151	3.3
August, 2d week	1894	64	28,900	877	3.0
August, 2d week	1895	13	3,900	349	9.0
August, 2d week	1896	28	7,400	1,184	16.0
August, 3d week	1895	4	1,450	87	6.0
August, 3d week	1896	18	5,900	340	5.8
August, 4th week (10 days)	1895	41	11,400	1,284	11.3
August, 4th week (10 days)	1896	10	8,941	329	3.7

GENERAL DESCRIPTION OF THE SMUT.

The smut usually first begins to appear in the leaves when the plant is three or four feet high, by forming small, raised, wrinkled patches, of a white color. Frequently the leaf takes a reddish color around these (plate V, lower right-hand figure). Later the spots turn black from the formation of spores, or if not very strongly developed they may disappear, leaving scarcely a trace.

When the plant is far enough developed to show some stalk, and the sheaths are apparent, the greater part of the smut is found about the junction of the leaf and sheath, extending upward and downward from this point, frequently forming rather large pustules (plate V, upper right-hand figure.)

When the tassels come out the flowers are often smutted, each of the floral organs forming a small pustule, while the whole tassel retains its shape (plate VI, lower figure). Sometimes, however, the whole tassel and even all the stalk above the ear is converted into a mass of smut.

A very characteristic point of attack is at the first joint below the tassel, where a large mass of smut appears, frequently causing the tassel to bend sideways.

The boils which form on the ears are usually the most conspicuous on account of their greater size. The boil may include the whole ear or only certain parts.

After the ears are developed, the only parts of the plant then

containing growing tissue that can be penetrated by the smut are the rudimentary ears at each node below the full ear, and the brace roots near the bottom of the stalk. Smut appears upon the latter but rarely. The rudimentary ears are, however, the most subject to attack of any part of the plant. The smut appears on these in great abundance in the latter part of the summer.

A smut boil appears first as a whitish glossy mass, which, during the ripening of the inclosed spores, may grow to considerable size—even as large as a person's head. As the spores mature within, the color changes to a darker shade. The thin covering finally bursts, exposing the mass of dark olive-green spores. The small boils may dry up without bursting.

DESCRIPTION OF THE SPORES.

The mass of nearly black powder which is contained in a ripe smut boil consists of innumerable minute grains. As previously stated, these grains are the spores of the smut, and serve for the propagation of the disease. Under the microscope, these spores are seen to be globose bodies of a brown color, having upon the surface numerous minutes spines. The spores measure about one thirty-three-hundredths of an inch in diameter. They vary at least between twenty-six ten-thousandths of an inch and forty-seven ten-thousandths of an inch.*

GERMINATION OF THE SPORES.

Under the proper conditions, which will be described below, the spores germinate. A tube protudes through a rent in the inclosing wall, which may branch indefinitely. Sooner or later, small oblong bodies are found on the ends of the branches. These secondary spores, or conidia, are blown about by the wind and are the actual agents for infecting the corn plant.

METHODS OF CULTURE OF THE SPORES.

During the last three years, numerous cultures have been made from time to time of the corn-smut spores. The cultures for the most part have been made in hanging drop cells. The cell is formed by gluing a glass ring to the ordinary microscopic slide. On top of this is placed a cover-glass. On the under side of this hangs the drop of liquid in which the spores are to be grown.

Usually the cover-glass was sealed to the ring by vaseline in order to prevent evaporation. These chambers allow the necessary amount of air for the growth of organisms and prevent the

*Hitchcock: Variation in spores of corn-smut. Science, XXII, 353.

evaporation of the liquid in which they are grown, while at the same time it is easy to watch the development of the culture under the microscope.

Some cultures were made by simply sowing the spores on moist slides kept in a glass damp chamber.

The majority of the cultures have been made in water and the modified Cohn solution used by Kellerman and Swingle in their cultures of smuts.*

Some cultures were made in manure decoction and agar-agar, but as a rule were not as satisfactory as the above.

Germination in Water.

The spores, after being in water 12 to 14 hours, begin to send out a tube, the promycelium, which breaks through the outer wall of the spore. The spores of corn-smut germinate quite readily, on the average three-fourths of them geminating. A constriction often forms in the promycelium, not far from the spore. (Plate I, Fig. 10.) The upper part, a long spindle-shaped body, may break off or remain attached. Often these are found in great numbers floating in the culture. These may soon cease growing or bear a few conidia, or sometimes grow out into a germ tube. The promycelium attains its full length in about 24 hours, and is divided into cells by three or four cross-partitions. About the time the partitions appear the promycelium begins to form small protuberances below the partitions, in one or more cells (Plate I, Fig. 7), and at the end of the apical cell these grow larger and the protoplasm from the cells passes into them. They continue growing for a few hours, and usually form fusiform bodies about 3 to 10 mmm long and 2 mmm wide, which soon grow smaller at the end next the promycelium and finally separate from it. These are the vegetative spores of the smut, and may be designated as conidia. Sometimes the conidia may be short and almost oval. Often they may bear one or more secondary conidia budded off from them before or after separation, in the same way that they were produced from the promycelium.

Spores that were germinated on clean slides in a moist chamber, but with no water on them, or those in water after the water had begun to dry up on those near the surface, produce in the air chains of conidia, each chain consisting of two to eight conidia (Plate I, Fig. 13; Plate II, Fig. 2; and Plate III, Fig. 2), each conidium being smaller than the one from which it grew. Brefeld mentions these occurring in nutrient solutions but not in water. Indeed the germination in water in our experiments has been much better than his. The air conidia have been seen abundantly in numerous

*Second Annual Report, Kansas Experiment Station, p. 230.

water cultures. In the dryer cultures, a long filament composed of short cells like the promycelium, but much longer than this, may be produced instead of the latter (Plate II, Fig. 2, a, b, c, d), or much more often such tubes, but usually smaller, may grow from the conidia as the water dries up (Plate III, Fig. 1).

Germination in Nutrient Solutions.

In modified Cohn solution and other nutrient culture materials, more of the spores germinate but not so soon as in water; usually the germination begins several hours, or even a day or more, later. The stronger the solution, the more the germination is retarded. The promycelium is much thicker and the whole growth more contracted than in water. (Plate III, Fig. 8.) The promycelium soon becomes as wide as the spore from which it emerged, and in a few hours begins the production of conidia very abundantly from all parts of the promycelium. These soon bear secondary conidia, which in turn keep on bearing other conidia in a series, until in two or three days the spore is surrounded with a mass of conidia, which continue growing as long as the nutrient material in the solution lasts. These chains of conidia often remain attached, and form irregular branches to the promycelium. The conidia that become detached settle to the bottom of the culture drop, giving it a white appearance. As the solution becomes exhausted, chains of air conidia are produced, as in water, but more abundantly. In the solution, the chains of conidia are irregular, and may be produced in any direction. The conidia are thin-walled and often full of vacuoles. The air conidia grow in straighter chains, and are more regular in shape and seem to be thicker walled. The chains are often much branched by the production of two to four conidia on the apex of the bearing conidium. The conidia are smooth and the contents usually homogeneous.

After the solution becomes exhausted, long, slender tubes—germ tubes—may be produced from the conidia and the ends of the promycelium or its branches.

If conidia are transferred to fresh liquid they go on budding and form colonies of conidia around each parent conidium, which itself grows larger and plumper and usually becomes septate (Plate III, Figs. 4, 5, 7), by one or more (usually one) partition.

No joints or fusions between different cells or conidia were seen in any case in the hundreds of cultures made, unless it be that two conidia have united in the case shown in Plate III, Fig. 5.

Some of the conidia were transferred to flasks containing modified Cohn solution, manure decoction or other nutrient liquid, and in a few days white spots began to appear on the surface of the

liquid, which increased gradually until the whole surface was covered with a delicate white membrane. This was made up of the chains of air conidia, which were produced in great abundance on the surface.

A few tests made with smut spores of different ages seem to indicate that the younger spores germinate better and quicker. The young spores just formed germinate best and grow more vigorously after germination. (Plate I, Figs. 10, 11, 12.)

INFECTION OF THE CORN PLANT BY THE SMUT.

It is well known that in the case of oat smut and most of the other grain smuts, the smut germ enters the plant when it is very young, before or some time after the young plant emerges from the ground. Hence a treatment of the seed to kill the smut spores attached to them will effectually prevent the disease in the plants. Many recent agricultural writers on smuts have recommended the same treatment for corn. Such a treatment, applied here for corn-smut* proved ineffectual, and, as stated in Bulletin 23, "Further investigation is necessary in order to determine the mode of infection before we can hope to employ rational means for prevention."

In the year 1893, infection experiments were begun by planting several pots of corn in the greenhouse variously infected with the spores of corn-smut, wet and dry, in the soil, on top the soil, on the grain, and in the sheath and leaves of the young plants as they came up, and a few with germinated spores on the young plants. The corn plants grew several feet high during the summer, but were very much more slender and less vigorous than normal. No sign of smut appeared on any of them. But observations seem to indicate that such weak plants in the field are not attacked by smut, so the negative result does not show conclusive evidence as to infection. At the same time, a few short rows of corn, about 100 stalks in all, were similarly treated with smut spores at different stages of their growth, from before germination of the corn up to infections in the young ears and tassels. The summer was very dry and the corn grew in an unfavorable situation, near a hedge, and did not do well. Smut appeared on three stalks, but in such positions that it was very probably not the result of artificial infection.

In the spring of 1894, several pots of corn were planted and the young seedlings infected with germinated material of corn-smut grown in manure decoction, sugar solution, and agar-agar, in different parts of the first two or three leaves, and at all ages up to two or three days old. This was done by blowing the infection material through a pointed glass tube. These plants grew some

*Bulletin 23, p. 101, Kansas Experiment Station.

better than those of the previous year, but no smut appeared on any of them.

The field experiments of the previous year were repeated and somewhat extended, and in addition a few infections made with the smut conidia.

A small plat of six rows was planted, as follows, May 28:

One and four, corn with fresh horse manure mixed with the seed.

Two and five, same with smut collected that spring (March 12).

Three and six, corn alone.

There was no material difference in the amount of smut on the different rows at the end of the season.

The drouth of this season entirely killed some of the corn in the infection plats, and damaged much of the rest; consequently the results could not be expected to be satisfactory, yet enough of the infections proved successful to encourage experiments on a larger scale the next year.

Several stalks of field corn, sweet corn and pop-corn were infected at different ages in the growing point with material containing the growing conidia of the smut, by thrusting a pointed glass tube into the upper end of the plant and blowing the infection in.

Ten stalks of pop-corn out of a plat of 40 stalks were infected as described above in the young ears from which the silks had not yet protruded. Two weeks afterward, two of the 10 ears (20 per cent.) were found to be badly smutted, while only one of the other 30 uninfected was found to be smutted, and that but slightly (3⅓ per cent.)

In the spring of 1895, a half acre of ground was set apart for experiments on corn and sorghum smuts. In the experiments with corn-smut the ground was planted in corn by hand, in rows 3½ feet apart, and the stalks 12-18 inches apart in the rows, making about 60 stalks to the row. The plats were cultivated and hoed twice during the season, which was very favorable, and produced a large yield of corn.

The following table shows the time of planting, method of infection and treatment of seed, and the result with each row:

Row No.	Treatment, infection, etc.	Date of planting	Smutted stalks June 24.	Smutted stalks July 8.	Smutted stalks Sept. 4.
49....	Hot water, 55° C., 15 minutes	May 9	0	1	17
50....	Untreated check row	"	0	0	9
51....	Germinated, and conidia applied when very young, before planting	May 31	0	0	10
52....	Untreated check row	May 9	0	3	5
53....	Conidia applied when sprout ½ to ¾ inch long, then planted	June 1	0	0	3
54....	Check row	May 9	0	6	21

Row No.	Treatment, infection, etc.	Date of planting	Smutted stalks June 24.	Smutted stalks July 8.	Smutted stalks Sept. 4.
55....	Conidia applied when sheath leaf was just broken through	June 4	0	0	5
56....	Check row	May 9	0	2	13
57....	Dusted with dry spores before planting	"	1	4	16
58....	Check row	"	0	5	12
59....	Hot water, 55° C., 15 minutes	"	1	4	16
60....	Check row	"	2	2	27
61....	Check row	"	0	4	15
62....	Check row	"	0	5	18
63....	Check row	"	0	3	12
64....	Check row	"	0	5	23
65....	Infected May 2 by atomizing on plants 3 inches high, water containing material from plate culture of *U. Mays Zea* in modified Cohn solution	"	0	4	4
66....	Check row	"	0	5	17
67....	Infected May 31 as in No. 65, except that in south half of row infected by pouring in top of plants; corn 5 to 6 inches high	"	1	4	19
68....	Check row	"	0	1	10
69....	Infected June 14 with glass pipette, same material in apical cornet, and by piercing sheath opposite growing point 2 to 3 inches from base; corn 10 inches high	"	0	3	19
70....	Check row	"	0	1	12
71....	Infected June 24 as in No. 69, 3 to 4 inches above the base; north half of row with spores just put in modified Cohn solution; south half from plate culture of same two days old; corn 2 feet high	May 11	0	23	27
72....	Check row	"	0	2	12
73....	Infected July 8, corn 3 to 4 feet high, by piercing the growing point with different materials. (See detailed description below.)	"	0	0	*25
74....	Check row	"	0	2	15
75....	Infected July 19 with conidia from flask culture in modified Cohn solution; first 12 stalks in ears just appearing; 20 stalks in tassels half out of upper leaf	"	0	2	20
76....	Check row	"	0	1	12
77....	Infected July 29 in silks and brace roots	"	0	3	16
78....	Check row	"	0	0	12
79....	Check row	"	0	0	11

* Almost all on the seventh to ninth leaves.

Rows 71, 73 and 75 were the only ones showing the result of infection. The north half of row 71 was infected June 24, when about two feet high, by piercing the stalk three or four inches above the base with a pointed glass pipette and forcing in smut spores put into modified Cohn solution. On July 2, nine days later, the corn had grown until the infected portion appeared at the top of the stalk and a few small smut postules appeared on the infected leaves. These increased as the corn developed until July 8, when the whole plat was examined for smut; 20 stalks out of 30 infected were smutted at the point of infection. In many of the stalks the whole upper part of the plant was a mass of smut, and entirely destroyed. The smut showed only near the infected part—none below this; and, in those that grew above the infected parts, healthy tops were produced. The other half of this row was infected at the same time and in the same manner, but with material in water from a plate culture of corn smut spores two days old. Only two stalks out of

the 30 infected showed smut which seemed to be the result of infection.

Row 73 was infected July 8, when the stalks were about four feet high, as follows: The first 15 stalks at the growing point, and a few at the lower nodes, with material from a culture (made two days before) of new spores grown this year in modified Cohn solution; infection unsuccessful. Seven stalks with last year's spores just put into manure solution: five smutted in the tassel and upper part of stalk, three of them badly. Six stalks with last year's spores just put into modified Cohn solution: one stalk showed infection, the tassel being badly smutted. Eight stalks with last year's spores in water: three tassels smutted. Nine stalks with new spores in modified Cohn solution: the smut pustules began to show on the upper leaves and tassels as they appeared, about 10 days after infection.

Row 75 was infected July 19, as follows: With mature spores from a pure flask culture of corn-smut in modified Cohn solution. The liquid from the flask containing the smut conidia was mixed with water. Twelve stalks were infected in upper end of ear, just protruding from the subtending leaf, and also in the base of two or three leaves immediately below this, in order to reach the rudimentary ears at the nodes. Three of the perfect ears were destroyed by smut, and eight of the others had the smaller rudimentary ears below the larger ear smutted. Twenty stalks were infected in the lower part of the tassel, which was about half out of the upper leaf. No tassels were affected with smut. The smut was first noticed August 1.

On July 29, row 77 was similarly infected in the ends of the young ears on 24 stalks, and the young silks protruding were liberally covered with the liquid containing conidia. A few infections were made in the brace roots at the base of the stalk. There is no conclusive evidence that any of the smut appearing later on this row was the result of infection. Only one ear was smutted.

Conclusions to be Drawn from the Infection Experiments.

The results obtained from the infection experiments, in addition to the copious field notes mentioned elsewhere, seem to indicate:

1. Infection may take place at any time of the season when the corn is growing, and does not depend so much on the time of the season as on the stage of development of the plant.

2. Infection may take place in any part of the plant where growing tissue is present, and at any time in its life, but scarcely ever before the plant has attained the height of three feet.

3. After the tissues are hardened, the smut cannot penetrate

them, and consequently infection does not take place in older parts of the corn, but only in the growing tissues. This growing condition is found in the young leaves when the first smut appears in the field; later mostly at the junction of the leaf and sheath, where cells are present for a long time in a state of active growth, and consequently exposed longer to penetration by the germ tubes from the condia; then in the flowers and young parts of the ear and tassel; while later in the season the only parts open to infection are the rudimentary ears, which develop after the larger ear at each joint on the lower part of the stalk.

4. The infection is probably through the conidia and not directly from the spores. Brefeld's investigations, mentioned elsewhere, seem to demonstrate this.

5. The period of incubation, or time between infection and the appearing of smut boils, is about 10 days.

6. It is probable that the early infections come from the spores of last year, which germinate on the ground at the first favorable weather in the spring, while the later and more abundant infections are from the new spores developed early in the season.

THE MYCELIUM OF THE SMUT AND THE DEVELOPMENT OF THE SPORES.

As was stated in the general description of the smut, the fungus during its early vegetative existence in the plant consists of slender colorless threads, penetrating between or through the cells of the host plant. In order to study these threads (the mycelium) and to observe the spores in various stages of development, we proceeded as detailed below.

Specimens of corn were chosen which showed smut boils in various stages of growth. Small pieces were cut out and placed immediately in a 1 per cent. solution of chromic acid. They remained in this about 24 hours. The pieces were then transferred to Steinach's draining boxes and washed for four hours and then placed in 15 per cent. alcohol. They were successively placed in alcohol of 30 per cent., 50 per cent., 60 per cent., 80 per cent., absolute, absolute a second time, a mixture of absolute alcohol and turpentine, and turpentine. They remained about 12 hours in each. Into the turpentine were placed bits of paraffine until no more would dissolve. Having remained in this 12 hours, more paraffine was added and the vessel set on a water bath and kept for a few hours at 55 to 60 degrees C. They were then transferred to pure paraffine having a melting point of 54 degrees C., and kept at 58 to 60 degrees on a water bath for several hours.

The effect of the chromic acid is to kill the living matter both of

the fungus and of the corn, and yet not shrinking or otherwise altering it, as would be the case if put at once into alcohol. The water is then gradually removed by means of the transfer through alcohol of increasing strength until it is finally in absolute alcohol. A sudden transfer would distort the material. In order to get the little blocks of tissue into paraffine, the alcohol must be replaced by a substance which will dissolve paraffine. For this turpentine was chosen. The object of imbedding the tissue in paraffine is to support it while being cut into thin sections for the microscope.

Each piece was placed in a little mold filled with the melted paraffine, and suddenly cooled by immersing the mold in cold water. The blocks of paraffine, each containing a piece of smut boil, were now ready for cutting. To do this, a block was carefully squared and stuck to a small cylinder of wood previously saturated with paraffine. This supporting cylinder was adjusted in the jaws of the microtome and a series of thin sections cut. A microtome is an instrument with a sliding knife by means of which very thin sections can be made.

The sections were placed on a glass slide in the order that they were cut. In order to stick them in place the glass was first covered with a very thin film of egg albumen (Zimmerman, Mikrotechnik, p. 38). By gently heating the slide till the paraffine melts the albumen is coagulated and the sections fastened to the glass. When the glass has cooled, the sections are treated with turpentine to dissolve the paraffine. The sections remain fastened to the slide during the various processes to which they are subjected. The sections are gradually transferred to water by the reverse of the method described above when they were deprived of water. For convenience, the various liquids were placed in Naples staining jars. The slides were tied together in a bunch, the adjacent surfaces being kept apart by a piece of twine placed between and the whole placed in one jar after another until all were in water. They were then placed in a dilute solution of haematoxylin (extract of logwood), where they remained until sufficiently colored (about 20 minutes). The filaments of the fungus and the young spores take up the color more readily than other parts, and hence can be much more easily distinguished under the microscope.

In order to make a permanent mount, and thus preserve the section for future study, they were mounted in Canada balsam, a colorless resin obtained from the balsam fir. For this purpose the water is again removed by gradual transfer to absolute alcohol, using, as before, the Naples jars, then to turpentine, when the Canada balsam is poured upon the sections and a thin cover glass

placed upon them. The balsam gradually hardens, and the sections are permanently mounted for study.

An examination of these sections shows that in the early stages of the smut the mycelium penetrates chiefly between the cells, but sends numerous branches into the cells. These branches are undoubtedly the sucking organs by means of which the fungus draws its nourishment from the host plant. These branches are usually more or less enlarged or branched at the extremities, and often come in contact with the nucleus of the cell. (Plate VII, Figs, 1, 2, 3, 4.) The threads of the mycelium while passing between the cells are usually quite thin and closely packed together, but become enlarged as soon as they enter the cell. The development of the disease is quite local. Apparently, after infection the mycelium penetrates but a short distance, but ramifies freely in the infected part. This part becomes a smut boil. There is probably a separate infection for each boil. Very soon after infection marked changes are seen to take place in the cells of the diseased part. They become abnormally active, due to the exciting influnce of the fungus. The cells increase rapidly in number, causing a swelling of the tissue at that point. Soon intercellular cavities are seen to form. The cells are pushed aside by a growing mass of the fungus threads. The mycelium in the cavities or pockets becomes in time a dense or felt-like mass (Plate VII, Figs. 5 and 6). The branches formed in these pockets sooner or later develop spores by abstriction. The end of each branch changes into a chain of spores.

At maturity, a smut boil consists of abnormally developed tissue, mostly thin-walled (parenchyma), in which are scattered pockets of spores (Plate VII, Fig. 9). The tissue of the host plant soon dries up, leaving a black mass of powder—the spores mixed with the remains of the tissue.

Plate VII, Fig. 7, shows a smut boil taken from the tassel. It represents a longitudinal section through a staminate flower (enlarged 8½ times). There were but five pockets in the boil, each filled with mycelium, as in Fig. 5. There was no mycelium observed in the mass outside the pockets except in their immediate neighborhood. The excessive development of the tissue seemed to be due entirely to the exciting action of the mycelium near the base of the flower. Fig. 8 is the same, enlarged. A weakly developed fibrovascular bundle is seen at the left.

SYNONYMY OF USTILAGO MAYS ZEAE (DC.) MAGN.

The most important synonymy is as follows:

Uredo segetum, Var. *Mays Zeae*, DC. Fl. Fr. II, 596. (1805.)
Uredo Maydis, DC. Fl. Fr. VI, 77. (1815.)
Caeoma Ustilago Zeae, Schw. Syn. Car. No. 485. (1822.)
Caeoma Zeae, Link. Sp. Pl. II, 2. (1824.)
Erysibe Maydis, Wallr. Fl. Crypt. Germ. IV, 215. (1833.)
Ustilago Zeae, Ung. in Corda. Ic. Fung. IV, 9. (1840.)
Ustilago Maydis, Corda. Ic. Fung. V, 3. (1842.)
Ustilago Schweinitzii, Tul. Ann. Sci. Nat. Ser. III, vol. 7, p. 86. (1847.)
Ustilago Zeae Mays, Wint. Pilze Deutschl. I, 97. (1884.)
Ustilago Mays Zeae, Magnus. Ustil. Pr. Brand. 72. (1895.)

BIBLIOGRAPHY.

There is considerable literature upon the subject of corn-smut. Below we have selected the more important titles. We have included those which present observations upon the development of mycelium or spores, germination of spores, and the technical original descriptions. We have excluded titles which apparently add no important data; or those which are of a purely popular character, such as descriptions in agricultural journals, and also such as deal with the injury to stock. In regard to the latter, we may say that the bulk of he evidence is in favor of the opinion that corn-smut is not directly injurious to stock. Bonafous is quoted at length because he reflects so fully the opinions of his day. The titles are arranged chronologically.

AYMEN. "Rech. sur les progres et les causes de la Nielle, p. 77 (1760)."

Tulasne quotes a paragraph from this (1st Mem. p. 85). Here he states that the source of the disease is in the tassel and describes the appearance of this. While all of the flowers of the tassel are smutted, this is not true of the ear, for a smutted ear may contain good grains which are probably fertilized by a neighboring stalk.

DE CANDOLLE. Flore Francaise, vol. II, p. 596 (1805).

At the end of the volume, under the "Additions et Corrections," he adds to No. 615, which is *Uredo segetum:*

"615. UREDO DES BLES, *Mays Zeae*. Lorsque l'uredo des bleds attaque les épis de mais, il s'y présente sous une apparence tres-remarquable: il boursouffle l'epidérme des grains, au point de changer leur forme et de leur faire presque atteindre la grosseur d'une prune: il détruit la substance farineuse, de sorte que cet épiderme, rempli de poussiere noire, ne ressemble pas mal a une vesseloup."

In Lamarck and De Candolle, Synopsis Plantarum (1806), the variety *Mays Zeae* does not appear, but we find (p. 47), under Uredo segetum: "In glumis et fructibus hordei . . . mays zeæ. In may semina usque ad magnitudinem nucis inflat et pulvere nigro replet."

BURGER. Abhandlung über Mais, p. 242-3 (1809).

A popular treatise on corn with a reference to corn-smut. He states that while other grains suffer severely from various maladies, corn is affected by but one, the smut ("Brand beule"). This may attack any part of the plant, but generally the ears. He refers to the works of Imhof and Tillet, who, he says, have proven that the dust of the boil, when eaten by man or animals or when introduced into wounds, is without injurious results. Also, that when the seed is treated with the dust and planted, smutted plants do not result, as in the case of wheat; that too much manure, too thick planting or shady situations are favorable to the disease.

DE CANDOLLE. Flore Francaise, vol. VI, p. 77 (1815). Original description of Uyredo Madis, as follows:

615a. UREDO DU MAYS. *Uredo maydis U. segetum* var. n. DC. Enc. bot. 8, p. 227. —*Charbon du mays.* Bosc. Dict. agr. 3, p. 339. Tillet. Mém. acad. Paris, 1760, p. 254. Imhof, Diss. in 4. Argentor. 1784, ex Bibl. Banks. 3, p. 431.—Carrad. Diss. in Giorn. pisan. 7, p. 301; 10, p. 265.

Je n' oserais pas affirmer d' une maniere bien positive, que l' urédo du mays soit une espece distincte du charbon; mais il présente des phénomenes si différens dans sa végétation, que j' ai peine a croire a leur identité. Il attaque tantôt la tige a l' aisselle des feuilles, tantôt les fleurs mâles, tantôt les grains mêmes du mays. La partie attaquée grossit et prend la forme d' une tumeur, d' abord charnue, puis entierement remplie d' une poussiere noirâtre, inodore, et tresabondante. Ces tumeurs ont depuis la grosseur d' un pois ou d' une noisette lorsqu'elles attaquent les fleurs mâles, jusqu' a celle du poing et au-dela lorsqu'elles attaquent la tige on même le grain. Lorsqu'elles sont parvenues a maturité, l' épiderme qui les recouvrait se rompt au moindre choc, et laisse échapper la poussiere. Cette plante parasite es donc intermédiaire entre le charbon et la carie: sa poussiere, comme celle du charbon, est inodore, composée de globules fort petits: comme celle de la carie, elle nait a l' intérieur des grains, pour se répandre ensuite au dehors. On trouve cette maladie dans tous les champs de mays situés dans des lieux humides au arrosés, et surtout dans les années pluvieuses.

SCHWEINITZ. Synopsis Fungorum Carolinae Superioris, p. 71. (1822.)

"33. Uredo. D. Ustilago. 485, 27, *Zeae* Sz. U. gigantea bipedalis spicas investit pulvere capillaceo nigrocinereo.

"Saepe madido anno, campos Zea obsitos devastat. Varie saepe torta. Affinior U. Carices, quam U. segetum."

In his Synopsis Fungorum in America Boreali media digentium. (1834), p. 290, he refers corn-smut to *Caeoma:*

"GENUS 211. CAEOMA.— α Subgen. UREDO.— 1. Ustilago.— 2812. 2. *C. U. Zeae*, L. V. S." etc.

LINK. Species Plantarum, pt. 2, p. 2 (1824).

Describes corn-smut under the name of *Caeoma Zeae*, as follows:

C. masculis pallidis, acervis inclusis bullatis germinis, sporidiis exacte globosis minutis nigris.

Uredo Maydis. De Cand. fr. 6, p. 77. Carradori Giorn. d. fisic. 8. p. 233.

Uredo segetum var. I. De Cand. fr. 2. p. 596.

Habitat in germinibus Zeae Mays cultae in Europa. Diagn. Germen intumescit, Caeoma continens, epidermis inflatur et percussa facillime rumpitur. Habitu igitur, uti monet De Candolle, facillime dignoscitur.

Not. Ab hoc diversum videtur, quamvis paucissimis tantum descriptum Caeoma quod Uredo Zeae Schw. fung. car. p. 45. gigantea bipedalis, spicas investit pulvere capillaceo (?) nigro cinereo, saepe madido anno campos Zea obsitos devastans, varie saepe tort a. Affinior U. Caricis dicitur, quam U. segetum.

The Uredo Zeae of Desmazieres is a rust (Notice sur quelques cryptogames recemment decouvertes en France, p. 34, 1840). "UREDO ZEAE, Nob. (Non *Uredo Maydis*, DeC.—*Caeoma Zeae*, Link.)

Maculis pallidis; acervis amphigenis, ellipticis, sparsis, approximatis, hinc inde confluentibus, convexiusculis, epidermide longitudinaliter crumpente. Sporulis exacte globosis, majoribus, rufo-brunneis. Habitat in foliis Zeae Mays."

WALLROTH. Flora Cryptogamica Germaniae pt. II p. 215 (1833).

Describes corn-smut under *Erysibe Maydis*, and adds:

"Ad receptacula Zeae Maydis cultae rarissime."

UNGER. Die Exantheme der Pflanzen p. 350 (1833).

Describes corn-smut in a popular manner. Says that if a smut boil is examined in a young state, no trace of spores is found—nothing but large cells filled with raw sap.

BONAFOUS. Historie Naturelle, Agricole et economique du Mais. p. 94, pl. XVIII (1836).

This is a very complete treatise upon corn, including history, varieties, cultivation, etc. Five pages are devoted to the smut ("Charbon du Mais"). After a description of the smut the author proceeds as follows [translated]:

"But in admitting with the botanists that the smut of maize is an agamous plant, whose spores penetrate through the cortical pores or through the roots, it is necessary also to say that several naturalists consider it, some with Liceti as a monstrosity; others with Tillet, Aymen, Imhoff, Parmetier, Re and others, as the effect of a lesion caused by the rupture of the cellular tissue and the diffusion of an altered sap. This opinion, which rests upon the identity observed between the form of an isolated *uredo* and that of a vegetable cell, is supported by the following experiences of Bayle-Barelle, made in the agricultural botanical garden of Pavia:

Grains of maize macerated in water, and impregnated with the powder which the tumors of the smut inclose gave birth to plants which did not show any trace of smut.

This powder introduced from the time of the first development of the plant, into the medullary body of several stalks, into the germ, into the parenchyma of the leaves, into the nodes, and into the roots, did not give rise to any sort of tumor.

On the other hand, a torsion given to vigorous stalks, in such manner as to destroy the cellular tissue without breaking the epidermis, caused the smut to develop upon the greater number of them, as Bayle-Barelle attests.

Finally, poor and shrunken grains plucked from the extremity of the ears produced, he adds, individuals of which the greater number were smutted.

Since then the opinion of the naturalists who attribute the smut to an organic lesion, finds itself supported by that of Mr. Turpin, according to which the greater number of the bodies known to botanists under the name "*uredo*," in place of being organized bodies living in the interior of the plants, would be nothing but pathological alterations of the "globuline" contained in the vessels of their cellular tissue. The "globuline" which this learned observer regards as the organic element of plants is, according to him, a vesicle in which are formed other little grains which, in successively increasing, destroy their envelope and become in their turn as well generative vesicles, in the body of which the same phenomenon repeats itself.

Nevertheless, if the ingenious theory of M. Turpin and the experiences of Bayle-Barelle, the last two especially, which I have however repeated without success, tend to invalidate the opinion of botanists, it is fair to cite in favor of these last, the analysis of smut made by M. Dulong (D'Astafort). His researches make it apparent that the smut of maize compared with fungi analyzed by Variquelin and by M. Bracomrot, offers to chemists as many points of agreement as one is able to expect from the analogy of the botanical characters of *Uredo Maydis*, DC., with those of other fungi. [Here follows an analysis.]

Our cultivators, prompt to seek out occasional causes, have conjectured that fogs, rains, dew, the humidity of the soil or of the air, winds or too raw manures favored the development of the smut.

The comparative cultures, which I have made on several points, appear to prove that it manifests itself indifferently under the influence of humidity or of drouth, under that of different manures or upon soils of a diverse nature, whether bare or shaded. Nevertheless, I am of the belief that I have observed that it was more frequent in warm and humid countries, that in general it attacked by preference the more vigorous stalks, and later varieties, and that, in the years when the smut of wheat manifested itself, that of maize multiplied in the same proportion.

"In 1752, the year in which the smut of maize was much seen, I caused the panicles to be cut," says Aymen, "before the stamens had opened. I left a few of them, however, at different points: that is to say, a sufficient quantity to fertilize all the plants of the corn. Those of which I had had the panicles cut early were not smutted: some of those upon which I had left the male flowers were infected with this malady."

Aymen repeated this experiment the following year, and had the same result.

We have advanced, and Losona among others has said that in the rotation of crops, wheat succeeding maize, the smutted powder of the latter communicated the smut to the former. To verify this fact I have mixed some wheat into an infusion of this powder in water, have sowed this wheat and have watered the soil with this water in all the stages of vegetation, and have caused the pulverent material to penetrate into the germinated grain, without obtaining any affirmative result.

Finally Bonnet, Duhamel, and other savants have put forth another hypothesis that an insect, invisible by reason of its smallness, deposited in the maize an irritating substance which modified the circulation of the fluids and gave rise to an abnormal vegetation by causing the fluids to flow toward the injured part.

But whether this excresence be a veritable plant, which I do not venture to affirm, whether it be a disease of the maize; or whether we attribute it to the sting of an insect, if the naturalists are in doubt concerning its origin, the cultivators know only too well the damage that this parasitic production does to the

harvests. It exhausts the plant, emaciates it, deforms it, opposes itself to the growth of the ear and often causes it to perish, or renders it barren.

This damage done to the harvests, in calling the attention of agriculturists to means of preserving the maize, has suggested to them to subject the seeds to the the action of quicklime, marine salt, potash, copper sulphate, sulphurous acid gas, and chloride of lime. They have suggested its cultivation at wider intervals, in order to give more space to the plants, to regulate the irrigation or to facilitate the flow of the water: to sow at a very slight depth, to exercise a scrupulous attention in the selection of the grain: and to reject those grains marked at the base with a black point, which a few regard as the rudiment of the smut.

We are not able to deny that several of these means may be useful; but the most certain one is to sow in well-prepared ground and to extirpate these excrescences as soon as they appear; in forestalling their development one prevents in the plant the evil which results from them.

Finally, examined in relation to its influence upon the animal economy, several facts prove to me that the smut of maize does not excite any noxious effect.

First. The workmen who, in separating the smutted ears, were obliged to breathe the powder which escapes from the smut are not inconvenienced by it at all; this again adds to the analogy between this production and that of the smut of wheat, the powder of which, according to the experiments which M. Tessier made some time ago, does not cause any evil result.

Second. Domestic animals, such as cats, geese, and chickens, to which I had fed for several days some of this powder in equal quantity mixed with their food, showed no repugnance nor experienced any accident; several times I have tasted this substance without any injurious result. Finally, cattle do not reject the smutted parts of maize: I have even seen cows eat a considerable quantity of it with impunity.

THE CULTIVATOR. Smut in Grain, p. 110 (1837.)

"Smuts are parasitic plants the minute seeds of which attach to the grain and are propelled through the sap vessels of the plant to the germs of the young grain. Salt and lime destroy the vitality of these seeds."

LEVEILLE. Recherches sur le development des Uredinees. (Ext. Ann. Sci. Nat. 1839, p. 9.)

Gives gross description and a scant record of microscopical characters, of Uredo du mais or *Uredo maydis*.

CORDA. Icones Fungorum, vol. IV, p. 8 (1840).

Corda's work is usually cited for *Ustilago Zeae*, Unger. The following is taken from the copy in the library of the Missouri Botanical Garden:

"Ustilago, Fries, Syst. III, page 517: Emend. Unger Einfl. p. 211; Uredo Ustilago, Persoon Syn. fung. p. 224: Caeoma, Link Spec. pt. 2, p. 1: Caeoma Ustilago Nees S. F. 1817. 2. p. 2: Aecidium Fries S. O. V. I, p. 198.

Hypthallus spurius. Sporae coacervatae, entophytae dein erumpentes et destruentes simplissimae, liberae, episporio tenui; nucleo farcto, medio cavo: hylo nullo.

"Wir haben diese so verschiedene Gruppe Entophyten von Caeoma abgeschieden, und als einfachste Form dieser Reihe, Uredo (s. Icon. fung. II. p. 2 Taf. VIII, Fig. 2.) entgegengesetzt. Bisher haben wir noch kein eigenthümliches organisirtes sporenbildendes Stratum in Gewebe der mit den Parisiten dieser

Gattung behafteten Pflanzen aufgefunden, sondern nur leere Raüme durch Zerstörung des Parenchymes entstanden, und mit zahllosen Sporen erfüllt. Bei Uredo sind die sporen mit einer zelligen Sporenhaut bekleidet, bei Caeoma sind sie acrogen und gestielt, nur hier sind sie einfach und stiellos. Zu Ustilago segetum und U. Zeae Unger, fügen wir folgende Art." Goes on to describe U. Phomicis.

In the next volume of the same work (vol. V, p. 3, 1842) he adds the following which is cited for *Ustilago Maydis*, Corda.

"Die gesammten Arten des Brands gehören hierher und haben in die Tropenwelt zahlreiche Repräsentanten. *Ust. Maydis* besitzt Oeltröpfchen am Sporenkern und eine warzige Sporenhaut. Vielleicht est es Sorisporium verwandt."

MEYEN. Pflanzen Pathologie, p. 102 (1841).

The author describes quite minutely the development of the spores and the microscopical appearance of the mycelium, and refers to a previous article which we have not seen (Ueber die Entwicklung des Getreidebrandes in den Mays-Pflanzen — Wiegmann's Arch. III. 1837. P. 419. Tab. X. F. 1; 1838, p. 162-163.) He closes with the following: "Diese Beobachtungen, welche am Mays so leicht zu wiederholen sind, zeigen sehr deutlich, dass die Brandbläschen nicht aus den Zellensaft-Kügelchen der Pflanzen entstehen, ja man sieht sogar, dass nicht einmal der grosse schleimige Zellkern, der in allen diesen Zellen vorkommt, zu jenen krankhaften Ablagerungen verwendt wird. Und ebenso gewiss lässt es sich hier entscheiden, dass der Brandstaub nicht in den Intercellulargängen gebildet wird, sondern aus kleinen parasitischen Pilzen hervorgeht, die sich im Innern von Parenchym-Zellen bilden und diese hierauf zerstören."

TULASNE. Memoire Sur les Ustilaginees comparees aux Uridinees (Ann. Sci. Nat. S. III. T. VII. 1847), p. 83.

Gives description and full synonymy of *Ustilago Maydis*, Corda. He also describes as a distinct species, *Ustilago Schweinitzii*, which is based upon *Uredo Zeae, Schw.* It appears, however, to be ordinary corn-smut.

DE BARY. Untersuchungen über die Brandpilze, p. 4. (1853.)

This author gives a very detailed description of the development of the fungus. He states that the threads make their way between the cells, finally branch copiously, the mass of interwoven branches forming intercellular cavities.

KUEHN. Die Krankheiten der Kulturgewächse, p. 70. (1859.)

Describes the appearance of the smut and the development of the mycelium. He adds to the observations of De Bary and explains correctly the development of the spores. He seems to be the first investigator to observe the germination of the spores. He states that the fresh or just ripened spores do not germinate in water, or only with great difficulty. They developed in January, however, in 24 to 26 hours. He seems not to have observed air conidia though his figure 23, e, probably represents one.

FISCHER DE WALDHEIM. Contribution to the Biology and History of the development of the Ustilagineae. (N. Y. Agr. Soc. Rep. 1870, Translated from Pringsheim's Jahrbücher für Wissenschaftliche Botanik. Vol. VII. Pt. 1-2. 1869.)

Gives a full historical introduction, and personal observations on the mycelium and spore formation of corn-smut as well as several other species of smut.

CLOS. Recherches sur le Charbon du Mais. (Journ. Agric. prat. France, 1871.)

A historical resume.

WOLFF. Der Brand des Getreides (1874).

Describes corn-smut. He did not succeed in germinating the spores and quotes Kühn. Describes briefly and figures the formation of the spores.

FISCHER VON WALDHEIM. A short monograph of the Ustilagineae, p. 41, 1878 (Russian).

Full synonymy with short description of spores.

KUHN. Ueber die an dem Grünmais und Futtersorghum vorkommenden Brandformen (Fühlings landwirthschaftliche Zeitung. XXVIII, p. 81, 1879.)

Description of corn-smut and methods of prevention. Recommends soaking seed in ½ per cent. solution of copper sulphate.

BREFELD. Untersuchungen aus dem Gesammtgebiete der Mykologie.

This series of works, one of the most important series published in the domain of cryptogamic botany, commenced in 1872, and has continued to the present time, the last part having been issued in 1895. An extended account of the methods of artificial culture of the saprophytic and parasitic fungi appears in part IV (1881.) Part V (1883.) contains further notes on methods of culture and observations upon the germination of the spores of a number of smuts, including corn-smut (Ustilago Maydis p. 67.) In 1881, he received a smut boil from a friend and at once attempted to germinate the spores in water, but to his astonishment failed.

Later, he accidentally let the boil fall and the spores were scattered in every direction, many falling into cultures of other spores which were near by. He was agreeably surprised to find that the spores germinated in these nourishing solutions with great readiness. It was not till the following spring that he succeeded in germinating the spores in water. [It is to be observed that we succeeded in producing abundant germination of fresh spores in water.] The author describes in detail the germination under different conditions and the appearance of the conidia. In his classification of smuts, he places corn-smut in the first type, along with oat-smut.

Part XI (1895) is devoted to experiments in artificial infection of certain plants with smut. The experiments upon corn-smut commence on p. 52. The infection was by means of fluid containing conidia.

These experiments are divided into four series. Space allows only a brief summary of the results.

Series I. Young seedlings. Very young seedlings could be infected to a slight extent, but older ones not at all. The author concludes that in nature the plants are not usually infected at this stage.

Series II. Plants about a foot high. These were infected in the cornet of rolled-up leaves at top by introducing a spray of the liquid. The results were very successful.

Series III. Female inflorescence. Results very successful. If only a part of the ear was treated with conidia, only that part showed the smut.

Series IV. Brace roots. It was somewhat difficult to find the roots in the right stage, but with proper subsequent protection the results were successful.

He concludes that if infected in a growing part a plant will under favorable conditions become locally smutted at that place, and that in nature the infection probably takes place by means of the air conidia. Numerous plates accompany the text.

BREFELD. Neue Untersuchungen über die Brandpilze und Brandkrankheiten II (Nachrichten aus dem Klub der Landwirthe zu Berlin 1888). Translated in Journal of Mycology, p. 1, 1890, from which the following notes are taken:

The author describes infection experiments here which afterwards appeared in part XI of his Untersuchungen described above.

KNOWLES. A Study of the Abnormal Structure induced by Ustilago Zeae Mays (Journ. Mycol. V. p. 14, 1889).

An account of the change in structure produced by smut.

PAMMEL. Fungus Diseases of Iowa Forage Plants (Monthly Review of Iowa Weather and Crop Service).

The author remarks that corn smutted badly around Ames, Iowa, in 1889, though that was a dry year.

MAGNUS. Die Ustilagineen (Brandpilze) der Provinz Brandenburg (Abhandl. Bot. Ver. Pr. Brand. XXXVII. p. 72 [1895.])

Discusses the synonymy, showing that corn-smut should have the name *Ustilago Mays Zeae* (D C.) Mag.

NORTON. A study of the Kansas Ustilagineae especially with regard to their germination (Trans. Acad. Sci., St. Louis VII p. 234, Nov. 9, 1896.

Remarks on germination.

Our experiments deal only with corn-smut, which, as has been shown, enters the host plant during the growing period by the penetration of conidia at some point in process of rapid growth. It should be noted that bunt or stinking smut of wheat, oat-smut and others enter the host plant by penetrating the very young seedling, and are therefore infected by spores upon the surface of the seed when planted. On the other hand, according to the experiments of Frank Maddox, of Tasmania, the loose smut of wheat obtains entrance through the flower, remains in the seed and produces the smut of the following season. (Frank Maddox, Eastfield Newnham, Tasmania, Wheat Growing, p. 24 [1895 ?]; also Experiments at Eastfield, pp. 2–3, 1895.)

Head Smut of Sorghum on Corn.

Ustilago Reiliana. Kühn Rabenhorst's Fungi Europaei exciccati; cent. XX (Dresden 1875) No. 1988.

This smut was found here in 1890 on sorghum, and an account of it published by Kellerman and Swingle[1].

Ustilago Reiliana was found in Italy by Passerini[2] in the male inflorescence of corn (*Zea Mays*) but has never been reported on this host from America until October, 1895, from this place.[3]

On July 10, 1895, Mr. George L. Clothier, while examining the corn fields on the College farm for *Ustilago Mays Zeae*, found a peculiarly smutted stalk which seemed so much different from the ordinary corn-smut that it was more closely examined and proved to be *Ustilago Reiliana.* During the remainder of the summer several fields near Manhattan were examined more closely for the smut and it was found to be quite common, though not in sufficient abundance to appreciably affect the corn crop.

Observations were also made on as many fields as possible in other parts of the state. In passing along the road through Geary and Morris counties, 25 to 30 miles south of Manhattan, several affected stalks were seen. In September, a trip was made to the northern part of the state to examine the smuts in the fields. Several fields in Phillips county were investigated but no *Ustilago Reiliana* was found. In passing through Smith county, some stalks of corn were seen that appeared to be affected with this smut, but there was no opportunity to examine them closely. The smut was found quite abundantly in fields near Webber, Jewell county, and one smutted stalk was observed in Republic county. The smut was also found at Superior, Neb., very close to the Kansas line. At Salina, the smu was found very common in several fields; many others, however seemed to be entirely free from it.

Ustilago Reiliana, unlike *Ustilago Mays Zeae*, attacks the whole plant, almost destroying it. On only one plant affected out of several hundred examined was any grain found and then only a few kernels. The smutted stalks are usually not over half as high as the unsmutted, and in weight are very deficient. Eleven stalks were weighed and averaged 539 grams each, while plants affected with *Ustilago Mays Zeae* from the same field averaged about 1,300 grams and healthy

1. Proceedings Kans. Acad. Sc. 1890, p. 158; also Bulletin 23, Kansas Experiment Station.
2. Passerini, La Nebbia dei cereali, 1876.
3. J. B. S. Norton, Bot. Gazette, Oct. 1895, p. 163.

plants averaged 1,500 grams or more. So if this smut should ever become abundant in this country, it may seriously damage the corn crop as it has the sorghum industry in other parts of the United States.

It may be possible that this smut is more abundant in the cornfields of America than appears now to be the case; for an observer who was not looking for both species might confuse them in the field in making a hasty examination, yet it is easy to distinguish the two if they are seen together.

Ustilago Reiliana appears in the tassels and ears as a rather hard, compact mass of smut of a rough granular appearance. It does not have the large soft swellings that *Ustilago Mays Zeae* has, but at first the ovate, pointed mass of smut is inclosed in a white membrane as is the case with *Ustilago Mays Zeae*, but this soon disappears. On older smutted places, the enlarged fibrovascular bundles of the corn give the smut mass a stringy, coarse appearance. The smut is usually seen best in the tassel or upper part of the plant, the whole upper portion often being converted into a smut mass just above the ear. When it attacks the ears, the husk usually conceals it until late in the season. The smut usually attacks all the ears, rudimentary ears or shoots on the stalk, converting them into masses of smut but not enlarging them. Often the tassel may not be smutted but usually is. Sometimes when the smut is not very bad on the stalk, the flowers are curiously deformed. The ears are almost always attacked and often a cluster of ears is borne where there is normally but one. Often instead of producing flowers, and when not actually smutted, the floral organs grow into long leaf-like projections (Pl. 2, upper figure). Sometimes a few smutted patches appear on the upper leaves. Plate VII shows both *Ustilago Mays Zeae* and *Ustilago Reiliana* on the same plant.

Microscopic Characters (Plate IV.) The spores are large, 7 to 14 mmm in diameter, averaging about 11 mmm. They are usually almost spherical, sometimes slightly angled or elliptical in outline. The outside is closely set with fine projections, color brown. Among the dry spores may be seen large numbers of colorless cells somewhat larger than the spores and usually in clusters.

The fresh spores germinate in water after 24 hours. A promycelium from 25 to 50 mmm long is produced, which is soon from 3 to 5 septate, and often branched, the branches frequently projecting at right angles. (Plate IV, Fig. 4.)

Usually only a few conidia are produced; these are short and ovoid, and when detached leave a distinct projection where they were attached (Plate IV, Figs. 5a and 6.) Sometimes a few secondary conidia are produced.

In modified Cohn solution the spores do not germinate for two or three days. But the growth is then very vigorous, and yeast-like conidia are produced in great abundance. The method of infection has not been determined.

SUMMARY.

The smut of corn is caused by the attacks of two species of parasitic fungi, the common corn-smut (*Ustilago Mays Zeae*), to which most of the damage is due, and sorghum-head smut (*Ustilago Reiliana*), comparatively rare on both corn and sorghum.

Common Corn Smut.

Table I shows that smutted corn-stalks bear one-third less grain by weight than clean stalks under the same conditions. In the comparison all stalks with a perceptible trace of smut were included among the smutted stalks. Table II shows that the smutted stalks are nearly as heavy as the clean stalks, the loss being in the grain.

The proportion of smutted stalks varies greatly, being in some cases as high as one-fourth (See table III), but this is unusual. Six per cent. will represent a fair average. Two hundred and six thousand, eight hundred and twenty-six stalks counted during the three years, in about 500 fields, showed 9,716 smutted stalks, or 4.7 per cent. The average of all counts made in August gives, however, 6.2 per cent. The total loss then on the average is 2 per cent. of the grain crop, assuming that the smutted stalks have one-third less grain than the clean stalks. During July the smut appears chiefly on the leaves, later it is most frequent upon the stem. The ears are less frequently affected but the damage is, of course, proportionately greater.

There is little difference in varieties of corn as to their susceptibility to smut. (See table IV.)

The smut does not usually make it appearance on the corn till it is two months old. Observations later in the season show that, other conditions being equal, all corn becomes about equally smutted, regardless of the time of planting. That is, early corn becomes smutted sooner than late corn, but finally both show about an equal amount of smut. (See table V.)

The spores of the smut, the black or dark-brown powder composing the smut boil, germinate in water or better in manure solution. In this way each spore forms a large number of smaller colorless spores, which in turn may be blown by the wind on the corn plant. The little spores or germs gain an entrance at some part of the plant which is in an active growing condition, such as the central part of the cone-shaped mass of young leaves at the end of the stalk, the young ears or tassel, or even the brace roots. A smut boil appears about 10 days after the entrance of the disease.

So far as our observations go, smut is more abundant in dry seasons, and in the drier localities.

Smut is usually more abundant where the soil has been recently manured, or on corn growing near stables, barnyards, etc. Such patches often show a greatly increased percentage of smut.

The smut cannot be prevented by soaking the seed in fungicides, as is the case with oat-smut and stinking smut of wheat.

Since manure forms a favorable breeding ground for smut, fresh manure should not be applied to corn ground, especially in damp soil, nor should corn be planted too close to sources of manure. By proper care in this respect, and by burning as many of the smut boils as possible, the disease can probably be kept within limits which will not cause more than 2 per cent. of damage. It seems scarcely practicable to do more, as the expense would be greater than the saving.

Sorghum Head Smut on Corn.

Appended to the observations on common corn-smut are some observations upon the much less common sorghum head smut on corn. This smut has as yet caused no serious damage.

EXPLANATION OF PLATES.

PLATE I. *Ustilago Mays Zeae*, spores and germination.

Fig. 1. Six spores, three longer than the normal forms, one in perspective × 1200.

Fig. 2. Three shrunken spores × 1200.

Fig. 3. Spore showing well marked walls × 1200.

Figs. 4, 5, 6, 7. Eight spores after 48 hours in water, showing different stages of germination × 1200.

Fig. 8. Spore after 38 hours in modified Cohn solution, with elongated, thread-like promycelium, conidium (?) forming on end × 1200.

Fig. 9. Germinated spore after seven days in water × 850.

Figs. 10, 11, 12. New spores just ripe and collected 10 days before germination, after 22 hours in water × 1200.

Fig. 13. Spore after 36 hours in manure decoction (Nährlösung), beginning to produce air conidia × 1200.

PLATE II. *Ustilago Mays Zeae.*

Fig. 1. View from microscope field, spores germinating and bearing conidia; water culture after 48 hours; conidia and portion of promycelium in lower right hand corner from spore not shown; some of the detached conidia are from other spores × 850.

Fig. 2. Air conidia and germ tubes; culture on moist glass plate in damp chamber, *a*, *b*, *c*, *d*, forms with long tubes, others usual form × 370.

PLATE III. *Ustilago Mays Zeae.* Conidial forms.

Fig. 1. Four conidia sending out germ tubes after 10 days in water × 1200.

Fig. 2. Air conidia after 10 days in water growing from branch of promycelium × 1200.

Fig. 3. Typical branch of air conidia from manure decoction (Nährlösung) × 1200.

Figs. 4, 5, 6, 7. Growing conidia from modified Cohn solution after three days on glass plate culture, sending out germ tubes, 4 and 5 with secondary conidia forming on the ends of these; 4, 5 and 7 show the septate conidia × 1200.

Fig. 8. Vigorously growing spore after 66 hours in modified Cohn solution × 1200.

Fig. 9. Portion of conidia colony in old almost exhausted modified Cohn solution. The conidia are more slender and smaller than in fresh nutrient liquid as in Fig. 8 × 1200.

PLATE IV. *Ustilago Reiliana.* Germinating spores × 1200.

Figs. 1, 2, 3, 4. Germination in water after three days; common forms. Fig. 5. After 48 hours in water, *a* with detached conidium showing point of attachment, *c* conidia from another spore not shown. Figs. 6, 7. Spores germinating after 36 hours in water, drawn 60 hours later.

PLATE V.—Figures one-half natural size.

Upper left-hand figure. Smutted ear.

Lower left-hand figure. Smut on rudimentary ears, lower part of stalk, breaking through sheath.

Central figure. Smut on joint below tassel, where it very frequently appears, causing the tassels to bend to one side, often at right angles.

Lower right-hand figure. Smut on leaf.

Upper right-hand figure. Smut at junction of leaf and sheath.

PLATE VI.

Lower figure. Smutted tassel. One-half natural size.

Upper figure. Deformation of ear, influenced by *Ustilago Reiliana.* No smut actually in the ear but occurring on other parts of the stalk. One-half natural size.

PLATE VII.

Figs. 1, 2, 3, and 4. Sections through stem of corn in the early stage of smut, showing cells penetrated by the mycelium. Figs. 2 and 3 show the nuclei attacked × 580.

Fig. 5. Stem near a small smut boil, showing one of the cavities or pockets filled with a mass of mycelium × 125.

Fig. 6. A portion of same × 580.

Fig. 7. Longitudinal section of affected staminate flower, showing mycelium pockets × 8½.

Fig. 8. A portion of same enlarged × 55.

Fig. 9. Section from nearly ripe smut boil showing a pocket of spores.

PLATE VIII. *Ustilago Reiliana* in the upper part of the corn plant. *Ustilago Mays Zeae* below; one-half natural size.

PLATE IX. *Ustilago Reiliana* on ears and rudimentary ears lower on the stalk.

PLATE X. *Ustilago Reiliana* in some of the flowers of corn tassel; one-half natural size.

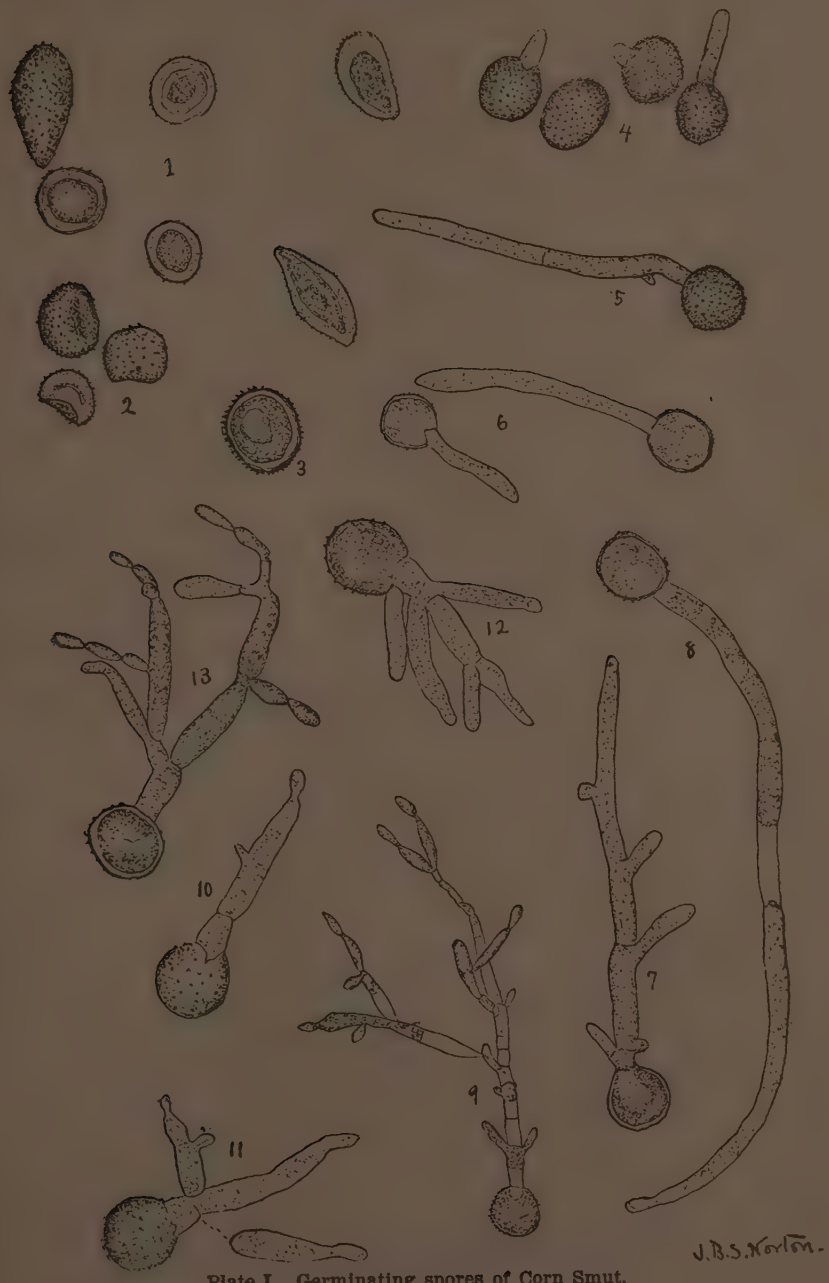

Plate I. Germinating spores of Corn Smut.

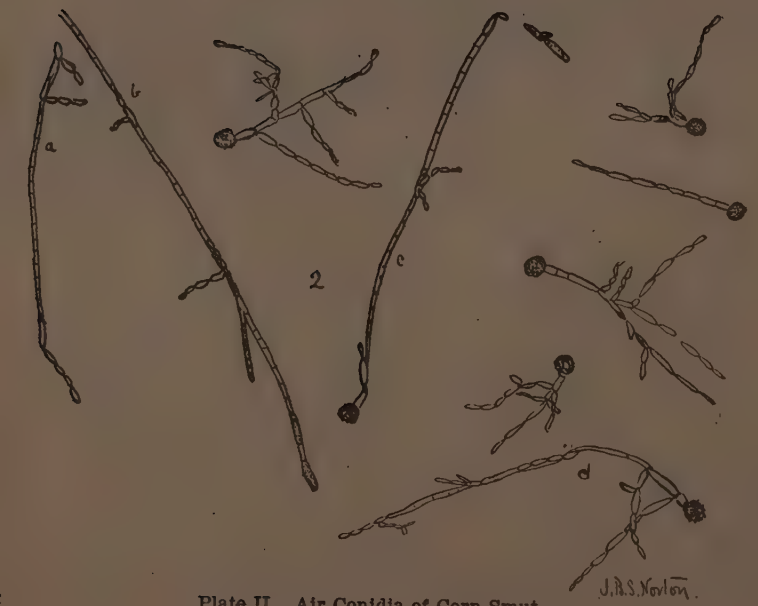

Plate II. Air Conidia of Corn Smut.

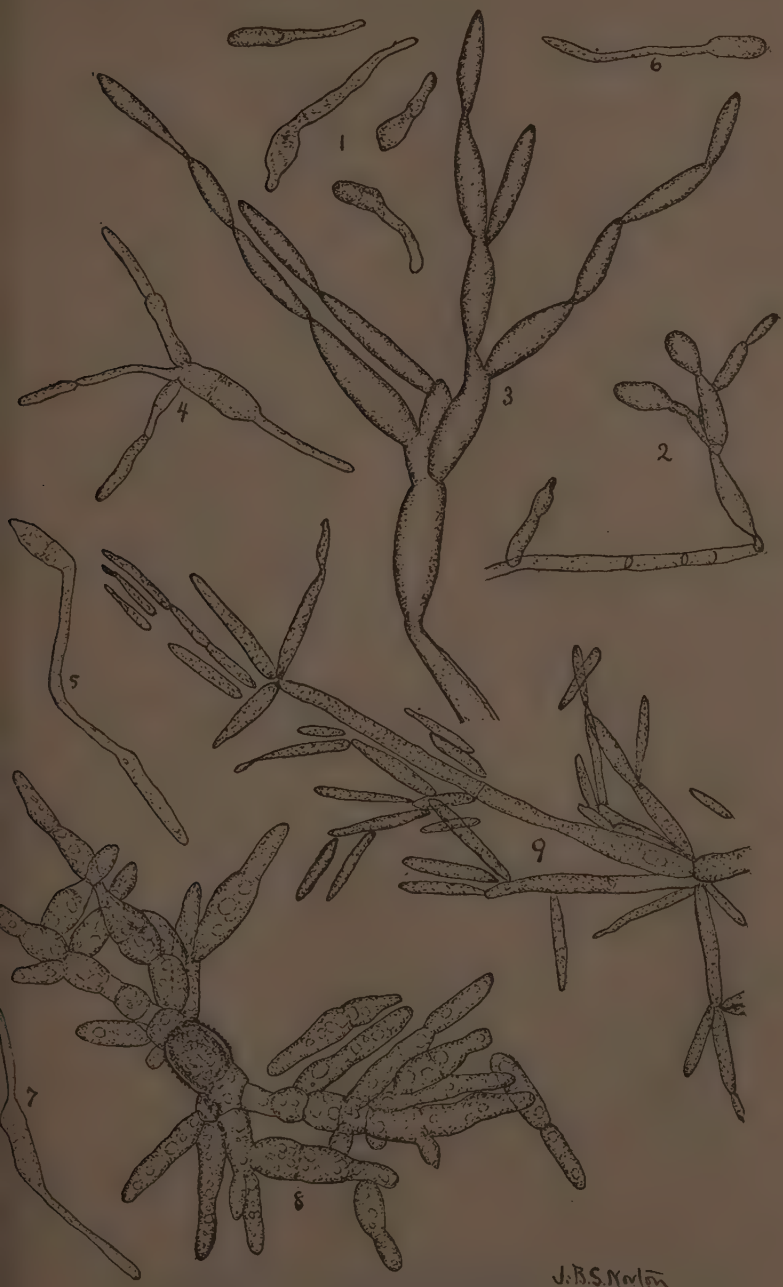

Plate III. Air Conidia of Corn Smut.

Plate IV. Germinating spores of Ustilago Reiliana.

Plate V. Corn Smut on various parts of plant.

Plate VI. Ear with U. Reiliana; tassel with U. Mays Zeae.

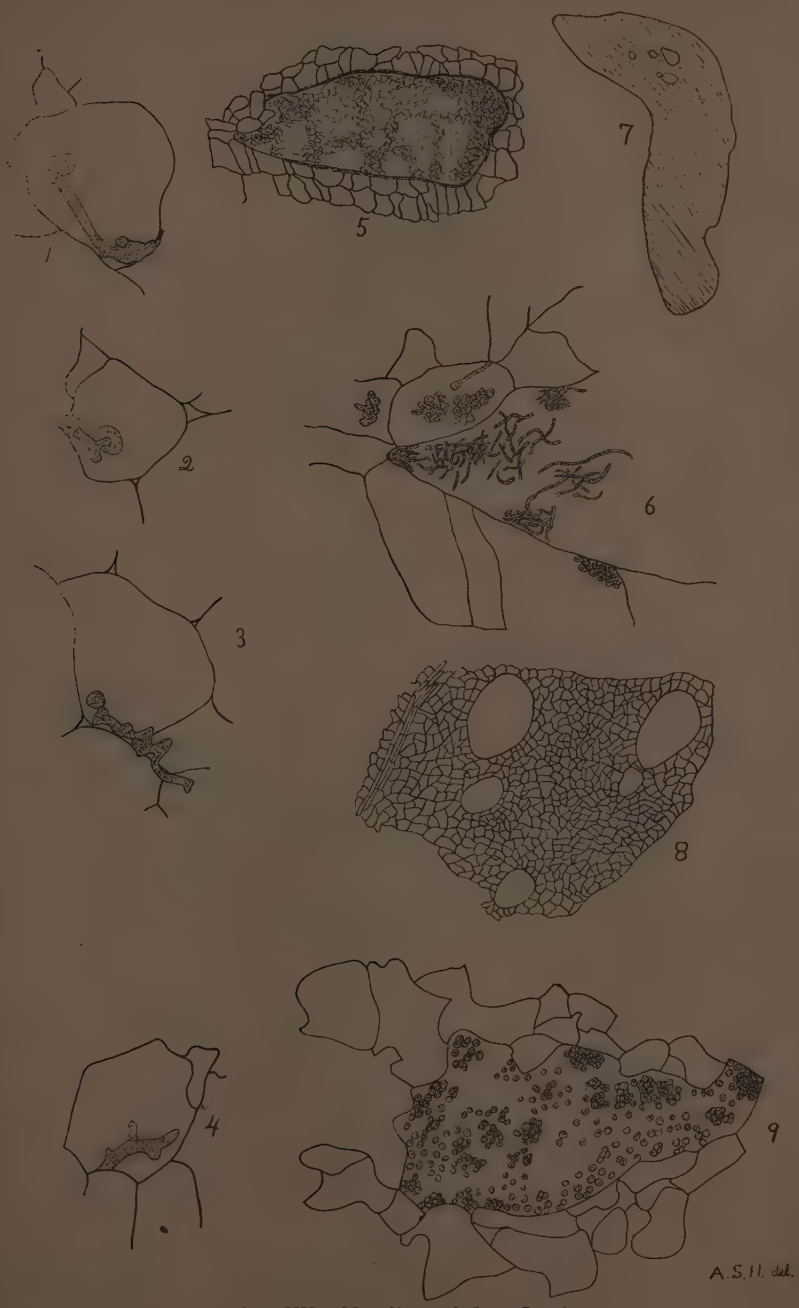

Plate VII. Mycelium of Corn Smut.

Plate VIII. Stalk showing both kinds of Smut.

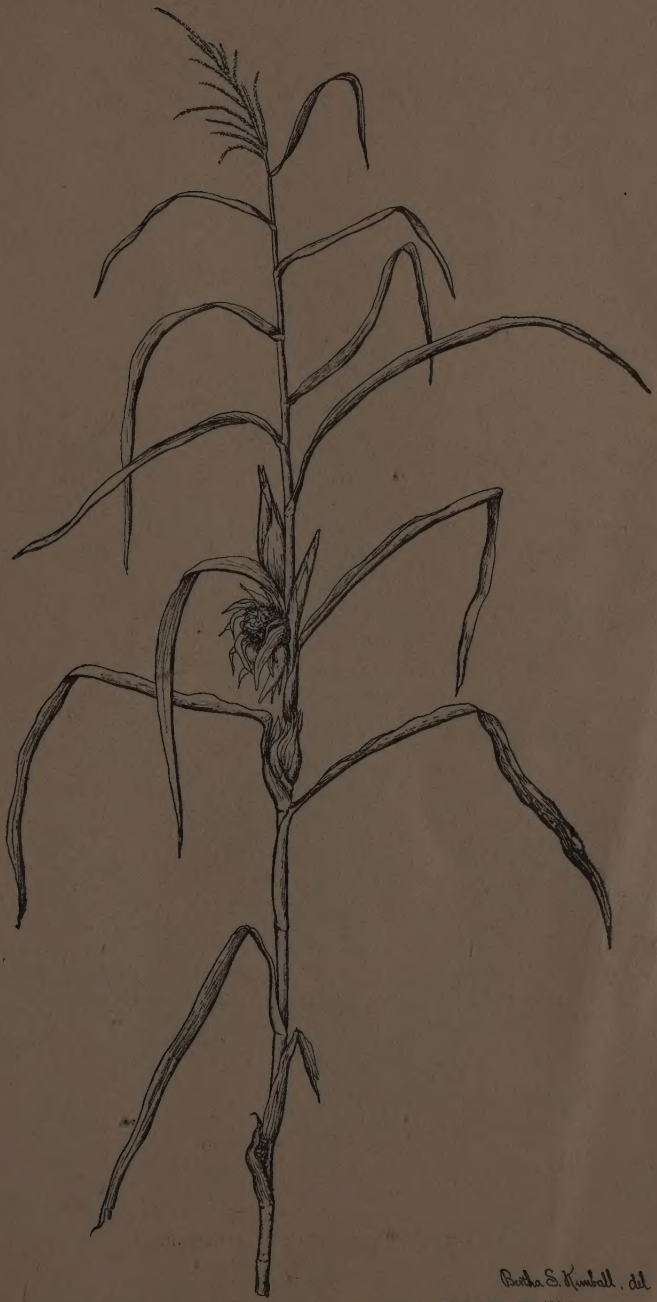

Plate IX. Rudimentary ears smutted with U. Reiliana.

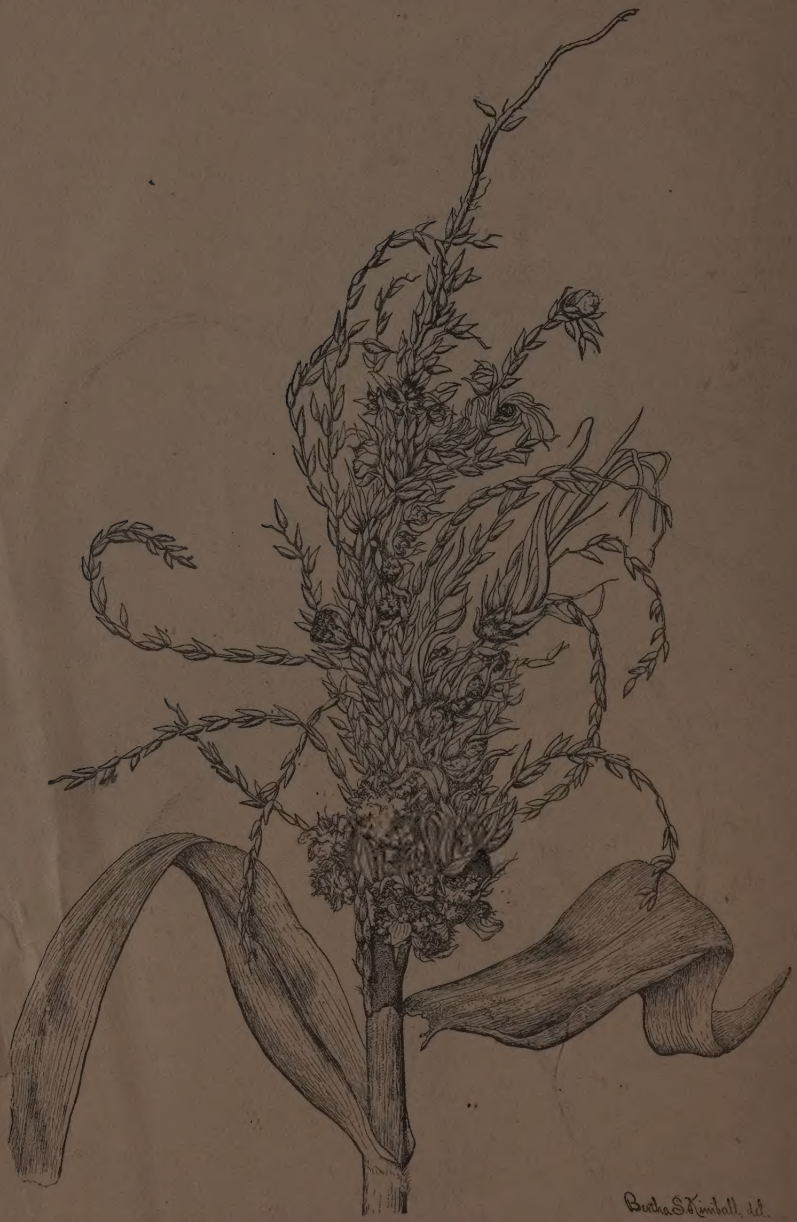

Plate X. Tassel with U. Reiliana.

NOTICE.

The bulletins of 1896 will include full reports of all completed experiments, and will not be reprinted with the annual report of the Station. They will be paged consecutively, beginning with No. 57, and a complete index will be furnished at the close of the year, to enable all who preserve them to bind in a single volume.

The bulletins and annual reports of this Station will be sent free to residents of Kansas, on application to the Secretary of the Experiment Station, Manhattan, Kas.

Published by order of the Council. I. D. GRAHAM, Secretary.

PREVIOUS PUBLICATIONS.

BULLETINS.

*No. 1, April, 1888, "Organization, Equipment, and Aims."
*No. 2, April, 1888, "Experience with Cultivated Grasses and Clovers."
*No. 3, June, 1888, "Life History of Two Orchard Pests."
*No. 4, September, 1888, "Experiments with Wheat."
*No. 5, December, 1888, "Sorghum, and Sorghum Blight."
*No. 6, July, 1889, "Silos and Ensilage."
No. 7, August, 1889, "Experiments with Wheat."
No. 8, October, 1889, "Preliminary Report on Smut in Oats."
*No. 9, December, 1889, "Experiment in Pig Feeding."
No. 10, May, 1890, "Notes on Conifers for Kansas Planters."
No. 11, July, 1890, "Experiments with Wheat."
No. 12, August, 1890, "Preliminary Experiments with Fungicides for Stinking Smut of Wheat."
No. 13, August, 1890, "Experiments with Oats."
No. 14, December, 1890, "Winter Protection of Peach Trees, and Notes on Grapes."
No. 15, December, 1890, "Additional Experiments and Observations on Oat Smut made in 1890."
No. 16, December, 1890, "Experiments with Sorghum and Sugar Beets."
No. 17, December, 1890, "Crossed Varieties of Corn, Second and Third Years."
No. 18, December, 1890, "Experiments with Forage Plants."
No. 19, December, 1890, "Germination of Weeviled Peas—Garden Notes on Potatoes, Beans, and Cabbage."
No. 20, July, 1891, "Wheat."
*No. 21, August, 1891, "Stinking Smut of Wheat."
*No. 22, August, 1891, "Smut of Oats; Smut and Rust of Wheat."
*No. 23, August, 1891, "Smut of Sorghum and Corn.'
*No. 24, September, 1891, "Staggers of Horses."
*No. 25, December, 1891, "Sorghum for Sugar."
*No. 26, December, 1891, "Varieties of the Strawberry."
*No. 27, December, 1891, "Crossed Varieties of Corn."
*No. 28, December, 1891, "The Experimental Vineyard."
*No. 29, December, 1891, "Oats."
*No. 30, December, 1891, "Corn."
*No. 31, December, 1891, "Sugar Beets."
No. 32, December, 1891, "Feeding Stuffs, and the Development of Grain Crops." "Soy Beans."
*No. 33, 1892, "Experiments with Wheat."
*No. 34, September, 1892, "Experiments in Feeding Steers."
*No. 35, December, 1892, "Actinomycosis Bovis, or 'Lumpy Jaw' of Cattle." "Some Observations upon Loco."
*No. 36, December, 1892, "Experiments with Sorghum and with Sugar Beets."
No. 37, December, 1892, "Experiments in Potato Culture."
No. 38, March, 1893, "Preliminary Report on Rusts of Grain."
No. 39, August, 1893, "Experiments in Feeding Steers, II."
No. 40, August, 1893, "Experiments in Wheat."
No. 41, December, 1893, "Effect of Fungicides upon the Germination of Corn."
No. 42, December, 1893, "Experiments with Oats."
No. 43, December, 1893, "Experiments with Sorghum and Sugar Beets."
No. 44, December, 1893, "Further Study of Native Grapes."
No. 45, December, 1893, "Experiments with Corn."

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*Out of print. The annual reports for 1888 and 1889 contain the subject-matter of Bulletins Nos. 2 to 9, inclusive.

No. 46, May, 1894, "Rusts of Grain, II."
No. 47, August, 1894, "Experiments with Wheat." "Experiments in Feeding Steers, III."
No. 48, December, 1894, "Six Years' Experience with Ensilage." "Some Forage Plants." "Renovating a Prairie Pasture."
No. 49, May, 1895, "Cattle Poisoning by Potassium Nitrate." "Mastitis."
No. 50, June, 1895, "Kansas Weeds, I.—Seedlings."
No. 51, June, 1895, "Steer Feeding, IV—A Comparison between Pure-Bred Shorthorns and Scrubs."
No. 52, September, 1895, "Kansas Weeds—Preliminary Circular on Distribution."
No. 53, October, 1895, "Pig-Feeding Experiments with Corn, Wheat, Kaffir Corn, and Cotton Seed."
No. 54, "Experiments with Oats."
No. 55, "Small Fruits by Irrigation."
No. 56, "Experiments with Corn and Kaffir Corn."
No. 57, "Kansas Weeds, III.—Descriptive List."
No. 58, "Cornstalk Disease of Cattle; Preliminary."
No. 59, "Experiments with Wheat."
No. 60, "Steer Feeding, V."
No. 61, "Kaffir-Corn, Corn- and Soy-Bean Meal for Feed."

REPORT FOR 1888.*—Contents.

Waste of Manure in Summering Manures in the Yard. Experiments in the Corn Field. Experiments with Wheat, including Bulletin No. 4. Forage Crops. The Milk and Butter Product as Influenced by Feeding. The Pressure of Ensilage on the Walls of the Silo. Relation of Rainfall to the Corn Crop. Shrinkage of Hay in the Mow. A Comparison of Varieties of Sorghum, including part of Bulletin No. 5. A Test of the Keeping Qualities of Sorghum. An Examination of Individual Stalks of Sorghum, with a View to Improving the Plant. A Trial of Fertilizers on Sorghum. A New Method of Milk Analysis for the Use of Dairymen. Spraying in the Apple Orchard. Observations upon Injurious Insects, including Bulletin No. 3. Trials of Varieties of Potatoes. Trials of Varieties of Peas. Trials of Varieties of Tomatoes. Sorghum Blight, including part of Bulletin No. 5. Hackberry Knot. Experiments in Fertilization of Varieties of Corn. Germination of Weed Seeds. The Fungous Parasites of Weeds.

REPORT FOR 1889.—Contents.

Experiments with Corn, Wheat and Forage Crops, including Bulletin No. 7. Silos and Silage, including Bulletin No. 6. Pig-Feeding Experiment, including Bulletin No. 9. Pigs from Mature and Immature Parents. Work upon Sorghum. Analysis of Feeding Stuffs. Composition of Corn at Different Stages of Growth. Ammonia and Nitric Acid in Atmospheric Waters. Comparative Trials of Garden Beans, of Peas, of Potatoes, of Tomatoes. Some Insects Injurious to the Bean. Loose Smuts of Cereals, including Bulletin No. 8. Crossing Varieties of Corn. First Year. Receptivity of Corn Silk.

REPORT FOR 1890.—Contents.

Summary of Bulletins 10 to 19, with index, and outline of other work undertaken.

REPORT FOR 1891.—Contents.

Summary of Bulletins 20 to 32, with index, and outline of other work undertaken.

REPORT FOR 1892.—Contents.

Summary of Bulletins 33 to 37, with index, and outline of other work undertaken.

REPORT FOR 1893.—Contents.

Summary of Bulletins 38 to 45, outline of other work, meteorological summary for 36 years, with index to bulletins and report.

REPORT FOR 1894.—Contents.

Summary of Bulletins 46 to 48, outline of other work, including irrigation experiments, with index to bulletins and report.

REPORT FOR 1895.—Contents.

Summary of Bulletins 49 to 56, outline of other work, with index to bulletins and report.

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*Out of print.